LOW FLOW CHARACTERISTICS IN ONTARIO

MAIN REPORT

OCTOBER 1990

Ontario

Environment
Environnement

Jim Bradley, Minister/ministre

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Report prepared by:
Cumming Cockburn Limited
145 Sparks Ave.
Willowdale, Ontario
M2H 2S5

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- Mr. B. Whitehead	River Systems Section, Water Resources Branch, Ministry of Environment
- Mr. P. Pilon	Hydrology Division, Water Resources Branch, Inland Waters Directorate
- Mr. D. Anderson	Water Survey of Canada Division, Inland Waters Directorate

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LOW FLOW CHARACTERISTICS

IN ONTARIO

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1.0 INTRODUCTION

1.1 General

The knowledge of the hydrologic conditions which exist during low flow periods can be of primary importance in undertaking a variety of water resources investigations. When analysing water quality conditions, the low flow characteristics within the watercourse are a major concern to both the user and the Ontario Ministry of the Environment. Some uses of low flow information include the following:

i) The analysis of municipal and industrial effluent discharges to streams
ii) Instream pollutant analyses (point and non-point sources including mixing zones)
iii) Reservoir design (low flow augmentation)
iv) Environmental approvals
v) Feasibility of small hydro developments
vi) Water supply and evaluation for water taking permits
vii) Base flow/groundwater recharge and/or contamination analysis
viii) Stream fisheries assessments
ix) Analyse effects of changes in watershed on low flows (e.g. deforestation, urbanization)
x) Agricultural
xi) Other

The identification of low flow characteristics within a watercourse is most easily accomplished using continuous hydrometric data recorded for the stream. Available data were previously analysed and published as a series of "Low Flow Characteristics" maps which were published several years ago (more than 10 years in most cases)

by the Ministry of the Environment (Ministry of the Environment, 1973-1978). Additional data (both temporally and spatially) are now available and it was, therefore, considered appropriate to update the available data base describing low flow characteristics across the Province of Ontario.

1.2 Study Objectives and Scope

The overall objective of the proposed investigation was to carry out an analysis describing the low flow characteristics at suitable Water Survey of Canada streamflow locations in Ontario. The following points summarize the scope of the investigations:

1. Update statistical low flow analyses for each of the following administrative regions:
   - Central
   - Southeastern
   - Southwestern and West Central
   - Northeastern
   - Northwestern
2. Undertake data base screening analyses to identify constraints on the data base
3. Produce extreme value analyses for suitable stream gauging locations (1, 3, 7, 15, 30-day durations) with greater than 10 years of data
4. Produce annual flow duration analyses, using daily data for suitable stream gauging locations
5. Produce monthly low flow analyses

2.0 METHODOLOGY

2.1 General

The available streamflow data base was obtained for all relevant Water Survey of Canada monitoring locations (see discussion in Section 2.2). Data analyses and screening were then undertaken in order to assess the usefulness of the data at each location prior to undertaking statistical analyses (see Section 2.3). Extreme values for selected low flow durations were then calculated for various recurrence intervals for both annual and monthly series using the techniques discussed in Section 2.4. Flow duration analyses were also undertaken utilizing the daily data base on both an annual and a monthly basis (see Sections 2.5 and 2.6). In most cases the extreme value analysis results should be used for low flow characteristic analysis. However, under certain conditions flow duration results of heavily regulated stations may give more conservative results. Computer drawn maps depicting low flow characteristics were then produced in order to summarize selected low flow statistics on a regional basis (see Section 2.7).

2.2 Data Base

The entire Water Survey of Canada daily streamflow data base for the Province of Ontario for the period of record to the end of 1986 was obtained in computer tape format.

Stations with a minimum of ten years of record were considered to have an appropriate record length for the purpose of this investigation. Stations inactive prior to 1981 were not considered in the analysis.

Several data management programs developed by Cumming Cockburn Limited were then used for extraction and analysis of data from the computer archives. First a program was written and executed to

check and screen the available data base at each station for missing data. A second program was then run to utilize this analysis to compute running averages for various durations and to pick the corresponding minimum annual low flow.

A third program sorted and analysed the available data to determine low flow values on a monthly basis. Average flows were determined and extracted for the annual consecutive low 1, 3, 7, 15 and 30 day durations and are available as part of the background files. Another program was used to compute flow duration curves as discussed in Section 2.5.

2.3 Data Analysis and Screening

The data were manually screened to remove station records which contained a significant number of zero low flow occurrences for all durations. These stations are listed in Table 1 and the screening results are discussed in Section 3.2.

The initial version of the Low Flow Frequency Analysis program was obtained from Environment Canada for use in the investigation (Pilon and Jackson, 1988). This program contains a set of data analysis and checking modules suitable for data screening and analysis (Pilon et al, 1985). At present there is some question concerning the reliability of the methodology for checking Independence for low flow data series (personal communication, P. Pilon, Water Resources Branch, Environment Canada).

The data screening process was undertaken to test the assumption that the data are reliable measurements and are mutually exclusive and represent independent random events which are free from trend. The non-parametric tests applied include the Spearman Rank Order Correlation Coefficient for Independence; the Spearman Rank Order Correlation Coefficient for Trend; and a general randomness test. The statistical tests were applied at the 1% and 5% levels of significance. (See Appendix A.3 for more details on the statistical tests.)

TABLE 1

Stations with Unacceptable Low Flow Data Set*

Appendix	Station	Station Name	Reason for Removal
F	02AD009	Ogoki River Diversion to Lake Nipigon	>30% Number of Occurrence of 0.0 Low Flow
E	02CA001	St. Mary's River at Sault Ste. Marie	Very large flows Aug - 1741 cms
E	02CB001	Mississagi River Below Aubry Falls	>30% Number of Occurrence of 0.0 Low Flow
E	02CC007	Mississagi River at Rayner Generating Station	>30% Number of Occurrence of 0.0 Low Flow
E	02CC009	Mississagi River at Red Rock Falls	>30% Number of Occurrence of 0.0 Low Flow
E	02CD004	Serpent River Below Quirke Lake	Only removed from the seasonal analysis
E	02DC007	Temagami River at Cross Lake Dam	Only removed from the seasonal analysis
E	02DD010	French River at Dry Pine Bay	Only removed from the seasonal analysis
E	02DD014	Chippawa Creek at North Bay	Arithmetic overflow
E	02DD017	French River at Chaudiere Dam	Only removed from the seasonal analysis
E	02DD018	Little French River at Freeflowing Channel	Only 2 years of record - deleted
E	02DD019	Little French River at Little Chaudiere Dam	Only 2 years of record - deleted
B	02EB012	Muskoka River at Highway No. 69	Only removed from the seasonal analysis
B	02EC005	Severn River at Washago	Only removed from the seasonal analysis
B	02EC007	Severn River at Little Falls	Only removed from the seasonal analysis
B	02EC016	Trent Canal Lock 42 near Washago	>30% Number of Occurrence of 0.0 Low Flow
B	02EC101	Uxbridge Brook at Uxbridge	Only removed from the seasonal analysis
D	02FF004	South Parkhill Creek near Parkhill	>30% Number of Occurrence of 0.0 Low Flow
D	02HA003	Niagara River at Queenston	Only 1 day duration could be extracted
D	02HB016	Bronte Creek at Progreston	Arithmetic overflow
B	02HC023	Cold Creek near Bolton	Only removed from the seasonal analysis
B	02HC027	Black Creek near Weston	Arithmetic overflow
B	02HC038	West Duffins Creek above Green River	Arithmetic overflow
B	02HD007	Soper Creek at Bowmanville	Arithmetic overflow
B	02HF004	Bob Creek near Minden	>30% Number of Occurrence of 0.0 Low Flow
E	02JD009	Montreal River at Mountain Chutes	Only removed from the seasonal analysis
E	02JD010	Montreal River at Lower Notch G.S.	>30% Number of Occurrence of 0.0 Low Flow
E	02JD011	Lady Evelyn River at Lady Evelyn Lake	>30% Number of Occurrence of 0.0 Low Flow
E	02JE012	Ottawa River at La Cave Rapids	>30% Number of Occurrence of 0.0 Low Flow
E	02JE021	Matabitchuan River at Rabbit Lake Dam	>30% Number of Occurrence of 0.0 Low Flow

* Program modifications were subsequently made and results are addended in the appropriate Appendices.

TABLE 1 (cont'd)

Appendix	Station	Station Name	Reason for Removal
C	02KA006	Perch Lake Inlet No. 3 near Chalk River	>30% Number of Occurrence of 0.0 Low Flow
C	02KA007	Perch Lake Inlet No. 4 near Chalk River	>30% Number of Occurrence of 0.0 Low Flow
C	02KA008	Perch Lake Inlet No. 5 near Chalk River	>30% Number of Occurrence of 0.0 Low Flow
C	02KD007	Madawaska River at Bark Lake	Only removed from the seasonal analysis
C	02KF014	Fall River near Fallbrook	Only removed from the seasonal analysis
C	02MB005	St. Lawrence River at Iroquois	Very large flows Aug = 5790 cms
C	02MC002	St. Lawrence River at Cornwall	Very large flows Aug = 5655 cms
F	04CA002	Severn River at Outlet of Muskrat Dam Lake	>30% Number of Occurrence of 0.0 Low Flow
F	04CA004	Severn River below Outlet of Deer Lake	>30% Number of Occurrence of 0.0 Low Flow
F	04CD002	Sachigo River below Outlet of Sachigo Lake	Only removed from the seasonal analysis
F	04DC001	Winisk River below Asheweig River Tributary	Arithmetic overflow
F	04DC002	Shamattawa River at Outlet of Shamattawa Lake	Only removed from the seasonal analysis
F	04GA001	Lake St. Joseph Outflow to Albany River	>30% Number of Occurrence of 0.0 Low Flow
F	04GA002	Cat River below Wesleyan Lake	Arithmetic overflow
F	04GB004	Ogoki River above Whiteclay Lake	Arithmetic overflow
F	04JD003	Long Lake Diversion to Lake Superior	>30% Number of Occurrence of 0.0 Low Flow
F	04JF001	Little Current River at Percy Lake	Arithmetic overflow
E	04LA002	Mattagami River near Timmins	Arithmetic overflow
E	04LG003	Mattagami River at Little Long Rapids	Arithmetic overflow
E	04MB003	Watabeag River at Watabeag Lake Dam	>30% Number of Occurrence of 0.0 Low Flow
E	04MC001	Abitibi River at Iroquois Falls	>30% Number of Occurrence of 0.0 Low Flow
E	04MC002	Abitibi River at Thin Falls	Arithmetic overflow
E	04ME003	Abitibi River at Onakamana	Arithmetic overflow
F	05PB009	Seine River at Sturgeon Falls G.S.	>30% Number of Occurrence of 0.0 Low Flow
F	05PE006	Lake of the Woods E. Outlet at Kenora P.House	Only removed from the seasonal analysis
F	05PE010	Winnipeg River at Whitedog Falls P.House	Arithmetic overflow
F	05QB006	Lake St. Joseph Diversion at Root Portage	>30% Number of Occurrence of 0.0 Low Flow
F	05QE005	English River at Caribou Falls	Arithmetic overflow
F	05QE007	English River at Manitou Falls	>30% Number of Occurrence of 0.0 Low Flow

* Program modifications were subsequently made and results are addended in the appropriate Appendices.

It must also be expected that a certain number of stations which are tested will randomly "fail" any given statistical test. Therefore, the binomial distribution was used to calculate the number of expected random failures over the entire data base for each region in order to assess the suitability of the low flow data on a regional basis. A tabulation of theoretical and actual "failure" results is summarized and discussed in Appendix A.3.4.

The effect of regulation was examined by further subdivision of the data base according to regulated and non-regulated stations. These results are tabulated in Appendices B to F and discussed in Section 3.2.

2.4 Extreme Value Analysis

An extreme value analysis was undertaken for each of the 1, 3, 7, 15 and 30-day durations for each of the stations.

For example, the minimum annual consecutive 7 day average low flow was determined for each year for the station record being analysed (see Section 2.2). The corresponding set of consecutive 7 day average low flows, therefore, represents an extreme value series to which a theoretical extreme value distribution can be fit for the purpose of determining the low flows corresponding to various recurrence intervals. For example, the $7Q_{20}$ low flow is often of interest for water quality investigation (i.e. the consecutive 7 day average low flow with an average recurrence interval of once in 20 years).

Previous investigations have found that the Gumbel III distribution has resulted in the best fit for extreme value analysis of low flows on most Canadian rivers. However, for samples with large negative skewness, the 3-Parameter Log Normal Distribution has proven to give adequate results and was adopted for these stations (Condie, 1983). A technical discussion of the fitting procedure is given in the users manual and briefly in Appendix A.

Parameter estimation for fitting of distributions proceeded in order of maximum likelihood, smallest observed drought and moments. The procedure utilized for analysis of each station record was identified on summary tables together with the results of the analyses (see Section 3.3. and Appendices B-F).

2.5 Flow Duration Analysis

The daily discharge data was extracted for each station and sorted by computer in order to derive empirical flow duration curves. The flow duration curves were summarized both numerically and graphically for each station (See Section 3.4 and Appendices B-F). The tabular summary presents the results of the flow duration computer output at 1% intervals across the flow duration curve.

2.6 Seasonal Analysis

In addition to annual computations referred to above, the flow duration curves and extreme value analyses were undertaken on a monthly basis to provide an information base for seasonal water resources investigations.

In order to reduce the amount of data tabulation, it was decided that only the results of the $7Q_{20}$ values would be summarized from the extreme value output. The results from the other 7-day duration recurrence intervals are available as part of the background files.

Flow duration curves were also tabulated on a monthly basis for comparison to the annual curves. A direct comparison with the plotted annual flow duration curve is, therefore, possible by using the numerical tabular summary. Typical results are discussed in Section 3.4.

2.7 Maps

Computer plotting was utilized as a cost-effective way of graphically summarizing selected flow characteristics. Base maps were digitized for each region. Data overlays were then prepared in order to produce two maps for each region, the first map summarizing selected low flow characteristics at each station, and the second map providing a corresponding discharge rate per unit area.

The resulting maps are discussed briefly in Section 3.5 and specific maps for each region accompany Appendices B to F.

3.0 STUDY RESULTS

3.1 General

This section summarizes general study findings and refers to specific results given in separate appendices for each of the five regions. (Appendices B to F).

3.2 Data Base Screening

3.2.1 Data Bases

For all regions, a total of 389 stations were found to have 10 years of record with the station being active within the last 5 years.

Other characteristics of the data base were also tabulated in Section 2 of Appendices B to F including, a brief station description, the period of record at each location, whether stream flows in the watershed are considered to be regulated or natural, and the drainage area of the watershed.

All of this information was extracted from the Water Survey of Canada HYDEX computerized data file maintained by Environment Canada. Statistical analyses were undertaken over the period of available record for both natural and regulated stations. However, subsequent to the data testing and extreme value analyses it was found that eleven data series classed as "regulated" included a portion of natural flow data. These stations were re-analysed with results addended in each Appendix as appropriate. Additional research indicated that three stations not recorded as mixed (natural and regulated flows recorded for the station) in the HYDEX file did consist of mixed periods. An analysis of these stations; 02GB001, Grand River below Brantford, 02GA003 Grand River at Galt, and, 02GA015 Speed River below Guelph, were re-analysed using only the regulated period of data. The period used was from 1945 (the

year after the Shand Dam was built) to the present for the Grand River Stations and 1975 to present for the Speed River data series (subsequent to the Guelph Dam construction). The results for the mixed $7Q_2$, $7Q_{10}$ and $7Q_{20}$ compared to the regulated period only are summarized as follows:

	Mixed Data			Regulated Data		
Station	$7Q_2$ m^3/s	$7Q_{10}$ m^3/s	$7Q_{20}$ m^3/s	$7Q_2$ m^3/s	$7Q_{10}$ m^3/s	$7Q_{20}$ m^3/s
02GB001	13.308	7.037	5.495	14.980	9.275	7.713
02GA003	5.822	2.176	1.679	9.186	5.120	4.156
02GA015	1.080	0.595	0.488	1.399	0.885	0.775

The results indicate an increase in the low flow values when using the regulated period only, compared to the analysis of the mixed record period. This may indicate low flow augmentation, or trend in the data series.

Users referring to analysis results for other regulated stations should investigate this aspect in more detail and analyses for all regulated stations used with care.

3.2.2 Screening Results

i) Zero Flows

Prior to undertaking the extreme value analyses a total of 23 data sets containing a significant number (*) of zero low flows for all durations were identified and removed from the data base (see Table 1). For example, for those stations where 30% or more of the available extreme flow data set was comprised of zero flow, it was arbitrarily assumed that use of this data base would result in a biased extreme value analysis. In addition, for short data sets (i.e. 10 years), reduction by 3 years results in insufficient data (7 years) with which to accurately fit the extreme value distribution.

A few stations which originally appeared to have 10 years of records were found to have a significant number of missing years in the detailed screening process. Those stations with minimal data were removed from the analysis (refer to Table 1).

ii) Arithmetic Overflow

Initial applicaton of the LFA program encountered an arithmetic overflow for a number of stations, which are identified in Table 1. The program was subsequently modified and the analysis results are included as addendums to Appendices B to F where appropriate.

iii) High Outliers

Initially the analysis of several stations with very large low flows (greater than 1000 m^3/s) could not be completed. These stations are identified in Table 1. Additional research was undertaken and the LFA program was subsequently modified to permit fitting of the extreme value distribution. These results are addended where appropriate to Appendices B - F (see Table 1).

iv) Statistical Tests

Statistical data analysis tests were undertaken as outlined in Section 2.3 and described in more detail in Appendix A.3. The available test statistics were recently made available as part of the LFA (Pilon, 1988) low flow analysis program. Previous application of these testing procedures to low flow series has been limited to date.

In general, it was found that a significant number of stations failed the non-parametric tests. Therefore, taken over the entire data base, application of these tests has indicated that the available data base of extreme low flows may exhibit some trend with some possibility of non-random characteristics.

The data were further analysed by subdivision of the available data set according to length of record (i.e. $\geq$20 years and <20 years)

and according to regulation code. However, it was found that neither the length of record, nor the possible effects of regulation could account for the conclusions of the test results. One explanation could be that the available record lengths are too short to permit reasonable application and interpretation of these non-parametric test results. A stronger possibility is that the available low flow data sets do exhibit trend and non random characteristics, which could possibly be attributed to slow cyclic change in groundwater levels or to climatic trends.

Additional testing was beyond the scope of the current investigations. However, further studies are recommended since these results may call into question the basic assumptions underlying application of the extreme value analysis technique for analysis of low flow characteristics.

v) Data Base

Extreme value analyses were undertaken on an annual basis for 344 stations and on a monthly basis for 330 stations. Further analysis was completed on the remaining stations with the revised program or by manual fitting on the annual data series.

Fourteen stations were assigned to more than one region since they may be representative of either region. The fourteen stations which appear in more than one region are:

Station I.D.	Central	South Eastern	Southwestern West Central	North Eastern	North Western
02HB011	√		√		
02HB012	√		√		
02HB013	√		√		
02HB016	√		√		
02HK002	√	√			
02HK003	√	√			
02HK004	√	√			
02HK005	√	√			
02HK006	√	√			
04HA001				√	√
04JA002				√	√
04JC002				√	√
04JC003				√	√
04JG001				√	√

TABLE 2

Summary of Statistics for Data Used in the Extreme Value Analysis

Region	*No. of Stations	Day Duration	Mean m^3/s	Standard Deviation m^3/s	Skew	Coefficient of Variation	Minimum Flow m^3/s	No. of Years
All	344	1	10.89	3.97	.82	.71	4.07	28
	344	3	12.50	4.02	.78	.66	5.78	28
	344	7	13.80	4.06	.75	.62	6.61	28
	344	15	14.32	4.01	.78	.59	7.27	28
	341	30	N/A	3.44	.84	.57	N/A	28
Northwestern	67	1	22.05	9.26	.78	.76	7.48	31
	67	3	24.35	9.46	.72	.72	8.79	31
	67	7	26.78	9.58	.67	.68	9.47	31
	67	15	27.97	9.82	.65	.65	9.47	31
	67	30	29.35	10.05	.55	.57	11.01	31
Northeastern	65	1	13.16	5.60	.79	.70	3.94	31
	65	3	16.06	6.02	.78	.64	6.25	31
	65	7	17.95	5.62	.62	.58	7.68	31
	65	15	19.12	5.67	.63	.53	8.87	31
	65	30	20.64	6.05	.59	.48	10.49	31
Southwestern & West Central	101	1	1.98	.49	.77	.67	1.24	26
	101	3	2.27	.44	.74	.62	1.58	26
	101	7	2.44	.44	.77	.58	1.75	26
	101	15	2.61	.49	.85	.56	1.88	26
	101	30	2.80	.58	1.03	.57	1.97	26
Central	76	1	1.45	.65	.39	.45	.52	24
	76	3	1.65	.66	.42	.42	.63	24
	76	7	1.89	.67	.44	.40	.81	24
	76	15	2.14	.73	.51	.41	1.01	24
	76	30	2.53	.91	.61	.40	1.18	24
Southeastern	49	1	27.36	7.36	1.62	1.05	12.22	28
	49	3	30.86	6.99	1.50	.96	18.58	28
	49	7	33.53	7.69	1.48	.93	20.97	28
	49	15	33.53	6.68	1.45	.89	22.51	28
	49	30	N/A	1.51	1.57	.90	N/A	28

*SOME STATIONS APPEAR IN MORE THAN ONE REGION.

The SPSS (Statistical Package Social Science, Norusis, 1986) was used to produce general statistics of the data base including the mean, standard deviation and coefficient of skew of the available low flow samples for different durations. These general statistics are summarized in Table 2.

With reference to Table 2, it is evident that the average of the mean low flow increases as the duration of low flow increases. The standard deviation decreases as a percentage of the mean as the duration increases. The mean skewness of the data decreases with the increase in duration.

Flow duration analyses were subsequently undertaken both on an annual and monthly basis. The flow duration results are summarized in Section 3.4, and the results tabulated on a regional basis in Appendices B to F.

3.3 Extreme Value Analysis

3.3.1 General

Tables summarizing the results of the extreme value analysis for each region are given in Appendices B to F for various recurrence intervals for each duration. An example of the presentation format is given as Table 3. The stations are identified by the Water Survey of Canada station number. The fitting method for the extreme value distribution is identified by a 3 letter code, MAX, MOM, SOD, PLN which stand for; method of maximum likelihood, method of moments, method of smallest observed drought, and the three-parameter log normal distribution respectively. (See also Appendix A.1 for additional information on the fitting procedures.)

The next three parameters appearing in the summary table are general statistics of the data sample including the mean n-day duration flow (m^3/s), Standard deviation, Skew (G), and the coefficient of

TABLE 3

EXAMPLE OF EXTREME VALUE TABULAR FORMAT

EXTREME VALUE LOW FLOW ANALYSIS FOR 7 DAY DURATION VALUES

STN#	METHOD	MEAN	STANDARD DEVIATION	G	C	REC (YRS)	MIN (m3/s)	RECURRENCE INTERVAL 1.005	1.010	1.111	1.250	2.0	5.0	10	20	50	100	200
02HE001	MAX	0.012	0.007	1.291	0.617	17	0.003	0.042	0.038	0.022	0.017	0.010	0.006	0.004	0.004	0.003	0.003	0.003
02HE002	SOD	0.003	0.004	1.276	1.210	17	0.000	0.021	0.018	0.008	0.005	0.002	0.000	0.000	0.000	0.000	0.000	0.000
02HK002	MAX	16.989	5.063	0.393	0.298	37	6.027	30.529	29.241	23.700	21.300	16.780	12.490	10.467	8.975	7.532	6.726	6.099
02HK003	MAX	1.774	0.692	0.522	0.390	27	0.661	3.930	3.686	2.713	2.330	1.680	1.162	0.956	0.823	0.712	0.659	0.622
02HK004	MAX	20.634	7.479	1.565	0.362	23	10.629	46.439	43.126	30.642	26.131	19.127	14.311	12.672	11.726	11.030	10.735	10.553
02HK005	MAX	0.904	0.522	0.388	0.578	18	0.148	2.711	2.488	1.631	1.312	0.803	0.436	0.305	0.226	0.165	0.139	0.122
02HK006	SOD	0.224	0.216	2.879	0.964	13	0.026	1.158	1.008	0.507	0.355	0.157	0.057	0.032	0.021	0.014	0.012	0.011
02HL001	SOD	1.941	1.476	3.763	0.760	71	0.534	8.411	7.352	3.858	2.813	1.477	0.814	0.653	0.582	0.541	0.529	0.523
02HL003	MAX	0.538	0.370	0.428	0.687	31	0.011	1.948	1.764	1.075	0.829	0.450	0.195	0.109	0.061	0.026	0.011	0.002
02HL004	MAX	0.423	0.304	1.457	0.720	29	0.021	1.507	1.365	0.835	0.646	0.357	0.164	0.100	0.064	0.038	0.027	0.021
02HL005	SOD	0.059	0.066	2.240	1.123	21	0.007	0.378	0.319	0.139	0.091	0.036	0.013	0.009	0.007	0.006	0.006	0.006
02HM002	MAX	0.372	0.262	1.195	0.705	30	0.000	1.267	1.156	0.731	0.573	0.322	0.141	0.077	0.039	0.009	0.000	0.000
02HM003	SOD	0.329	0.504	3.044	1.532	28	0.034	3.085	2.468	0.826	0.473	0.145	0.051	0.038	0.034	0.033	0.033	0.033
02HM004	SOD	0.032	0.023	0.782	0.720	21	0.006	0.119	0.107	0.063	0.048	0.026	0.013	0.008	0.006	0.005	0.004	0.004
02HM005	SOD	0.058	0.089	1.625	1.553	17	0.000	0.528	0.429	0.153	0.089	0.025	0.004	0.001	0.000	0.000	0.000	0.000
02HM006	MAX	0.113	0.067	1.123	0.593	16	0.033	0.382	0.344	0.206	0.160	0.095	0.056	0.045	0.039	0.035	0.034	0.033
02HM007	MAX	1.183	0.552	0.196	0.467	13	0.221	2.620	2.482	1.889	1.634	1.159	0.713	0.506	0.355	0.211	0.131	0.070
02KA002	MAX	423.844	85.688	0.044	0.202	36	246.700	641.884	621.782	534.359	495.910	422.320	350.559	315.804	289.624	263.746	248.934	237.197
02KA003	SOD	0.002	0.003	2.441	1.599	20	0.000	0.020	0.017	0.006	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000
02KA004	SOD	0.000	0.000	2.798	2.995	19	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02KA005	SOD	0.000	0.001	2.924	2.975	18	0.000	0.005	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02KB001	MAX	12.485	4.824	0.863	0.386	71	5.880	31.203	28.682	19.404	16.159	11.292	8.132	7.119	6.560	6.167	6.009	5.916
02KC009	MAX	4.934	1.485	0.681	0.301	61	2.300	9.443	8.951	6.953	6.151	4.762	3.614	3.143	2.830	2.561	2.427	2.333
02KC014	SOD	0.530	0.215	0.814	0.406	16	0.282	1.326	1.219	0.825	0.687	0.481	0.347	0.304	0.280	0.263	0.256	0.252
02KD002	MAX	3.020	1.471	0.985	0.487	71	0.089	7.328	6.882	5.027	4.259	2.886	1.687	1.168	0.808	0.484	0.315	0.191
02KD004	MAX	16.862	4.474	0.264	0.265	57	6.671	28.527	27.463	22.806	20.741	16.751	12.800	10.857	9.376	7.894	7.035	6.346
02KD007	SOD	1.282	2.281	1.663	1.779	44	0.000	13.932	11.030	3.451	1.877	0.454	0.066	0.017	0.004	0.000	0.000	0.000
02KE005	MAX	13.848	8.500	1.440	0.614	38	1.983	42.947	39.275	25.324	20.224	12.209	6.586	4.631	3.486	2.628	2.259	2.028
02KF001	SOD	6.365	3.405	1.447	0.535	7	3.240	20.209	18.138	10.938	8.617	5.412	3.604	3.103	2.855	2.700	2.645	2.616
02KF005	MAX	550.569	126.545	0.813	0.230	26	363.700	979.003	926.702	724.724	649.162	527.556	438.725	406.546	387.104	372.033	365.304	360.975
02KF008	MAX	7.368	2.113	1.252	0.287	68	4.611	15.503	14.393	10.335	8.930	6.843	5.511	5.091	4.863	4.705	4.642	4.605
02KF009	MAX	548.194	111.943	0.270	0.205	71	370.600	900.643	860.659	700.536	637.549	530.656	445.329	411.502	389.623	371.346	362.534	356.488
02KF010	SOD	0.391	0.361	1.995	0.923	15	0.064	1.974	1.714	0.859	0.603	0.277	0.115	0.076	0.059	0.049	0.046	0.044
02KF011	SOD	0.091	0.096	1.179	1.055	15	0.011	0.535	0.457	0.211	0.142	0.059	0.021	0.013	0.010	0.008	0.008	0.007
02KF012	MAX	0.289	0.080	0.493	0.278	15	0.167	0.539	0.510	0.396	0.352	0.278	0.219	0.196	0.181	0.169	0.164	0.160
02KF013	SOD	0.182	0.138	0.986	0.757	15	0.024	0.691	0.622	0.370	0.282	0.150	0.064	0.037	0.021	0.011	0.006	0.004
02KF014	SOD	0.237	0.353	2.409	1.490	12	0.002	2.062	1.690	0.628	0.373	0.109	0.018	0.003	0.000	0.000	0.000	0.000
02LA004	MAX	5.834	1.831	0.270	0.314	38	2.391	10.953	10.435	8.264	7.355	5.705	4.232	3.578	3.118	2.695	2.471	2.304
02LA006	SOD	0.188	0.304	2.192	1.622	17	0.009	1.848	1.479	0.490	0.277	0.076	0.018	0.010	0.008	0.007	0.007	0.007
02LA007	SOD	0.165	0.220	1.673	1.332	17	0.013	1.290	1.065	0.414	0.254	0.086	0.026	0.015	0.012	0.011	0.010	0.010
02LB005	MAX	1.333	1.044	1.516	0.783	56	0.000	5.106	4.604	2.746	2.091	1.100	0.448	0.236	0.118	0.034	0.000	0.000
02LB006	MAX	0.218	0.106	0.811	0.485	19	0.074	0.592	0.544	0.362	0.297	0.195	0.126	0.102	0.089	0.079	0.075	0.072
02LB007	SOD	0.053	0.104	2.994	1.950	37	0.000	0.644	0.501	0.144	0.075	0.016	0.002	0.000	0.000	0.000	0.000	0.000

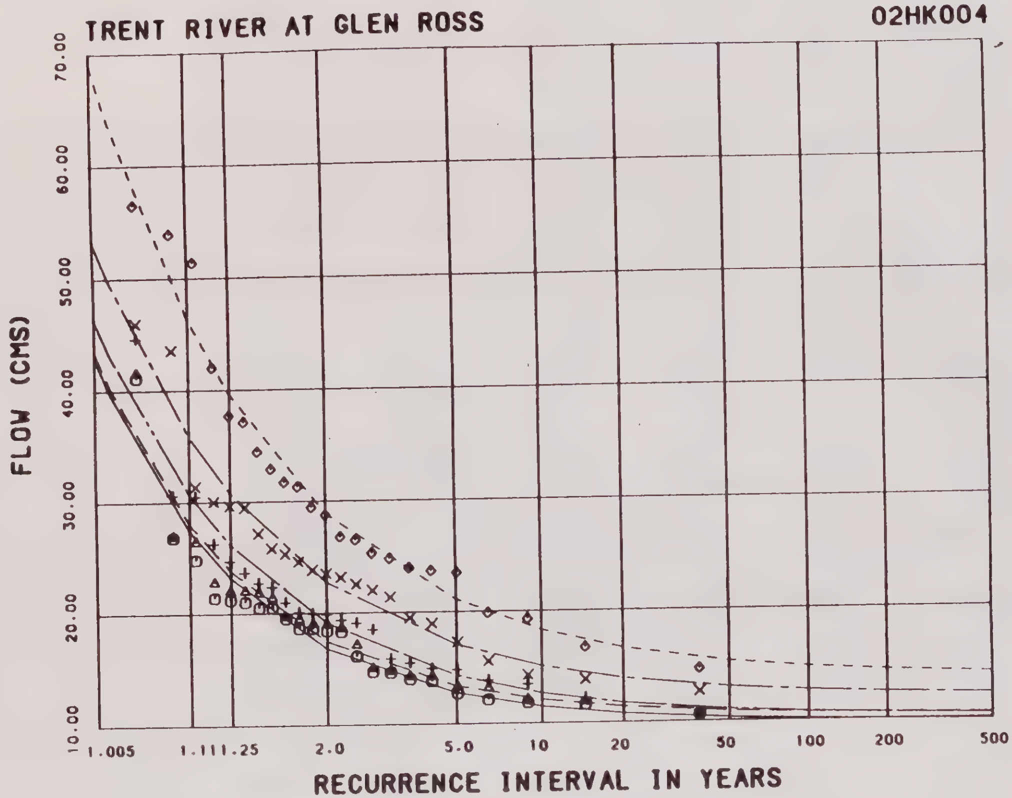
variation of record (C). The next two columns of the tables give the number of years of record available and the minimum observed average low flow for the particular duration for the available data set. Finally, the estimated flow for the various recurrence intervals are listed for each station.

3.3.2 Annual

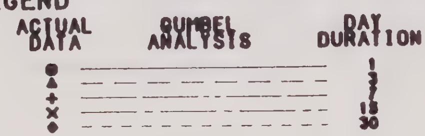
Extreme value frequency curves were plotted for each location and are available in Appendices B to F. An example graph is given in Figure 1 which summarizes the actual data and the fitted curve for the 1, 3, 7, 15 and 30 day durations for the Trent River at Glen Ross, Water Survey of Canada Station Number 02HK004.

A statistical summary of average unit area low flow characteristics was also undertaken and is summarized in Table 4. Area average low flow rates (litres/second/kilometre^2) together with standard deviation for the 5 durations were tabulated for all the regions for the 2 to 50 year recurrence intervals.

It is interesting to note that in most cases, the standard deviations are approximately equal to or greater than the corresponding mean flows. Low flows are consistently higher than the Provincial average in Northwestern, Northeastern and Central Region and consistently lower in the Southwestern and West Central/Southeastern Regions. However, it should be recognized that this finding may be due to the effects of the drainage area. For example, gauged watersheds in Northern Ontario tend to be larger than watersheds in Southern Ontario. Therefore, if the relationship between watershed area and low flow is non-linear the corresponding statistics may be biased.



LEGEND



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EXAMPLE OF LOW FLOW FREQUENCY CURVES

FIGURE 1

TABLE 4

Unit Area Average Low Flows

Region	Day Duration	2 Mean	2 (Std. Deviation)	5 Mean	5 (Std. Deviation)	10 Mean	10 (Std. Deviation)	20 Mean	20 (Std. Deviation)	50 Mean	50 (Std. Deviation)
		Recurrence Interval (years), 1/s/km²									
All	1	1.59	(1.40)	1.10	(1.12)	0.89	(1.00)	0.75	(0.92)	0.62	(0.85)
	3	1.74	(1.54)	1.24	(1.25)	1.02	(1.12)	0.87	(1.02)	0.73	(0.93)
	7	1.91	(1.90)	1.38	(1.39)	1.15	(1.24	0.99	(1.14)	0.84	(1.03)
	15	2.08	(1.79)	1.52	(1.49)	1.29	(1.34)	1.12	(1.24)	0.97	(1.13)
	30	2.31	(1.88)	1.68	(1.57)	1.43	(1.43)	1.25	(1.32)	1.09	(1.22)
Northwestern	1	1.76	(1.17)	1.24	(0.92)	1.02	(0.80)	0.85	(0.73)	0.70	(0.68)
	3	1.86	(1.30)	1.33	(1.01)	1.09	(0.87)	0.92	(0.78	0.77	(0.71)
	7	1.98	(1.53)	1.43	(1.20	1.18	(1.03)	1.00	(0.91)	0.82	(0.79)
	15	2.08	(1.60)	1.50	(1.26)	1.24	(1.08)	1.05	(0.94)	0.87	(0.82)
	30	2.20	(1.56)	1.60	(1.32)	1.33	(1.14)	1.13	(1.00)	0.94	(0.87)
Northeastern	1	1.93	(1.14)	1.24	(0.80)	0.96	(0.68)	0.77	(0.61)	0.60	(0.57)
	3	2.21	(1.37)	1.49	(1.01)	1.19	(0.86)	0.97	(0.76)	0.78	(0.70)
	7	2.48	(1.63)	1.72	(1.24)	1.40	(1.06)	1.16	(0.94)	0.95	(0.83)
	15	2.71	(1.73)	1.92	(1.36)	1.58	(1.19)	1.35	(1.07)	1.14	(0.97)
	30	3.08	(1.79)	2.18	(1.46)	1.81	(1.31)	1.55	(1.20)	1.31	(1.12)
Southwestern & West Central	1	1.14	(1.17)	0.76	(0.96)	0.67	(0.88)	0.52	(0.83)	0.44	(0.78)
	3	1.24	(1.24)	0.85	(1.03)	0.70	(0.95)	0.61	(0.89)	0.52	(0.83)
	7	1.37	(1.34)	0.97	(1.12)	0.81	(1.03)	0.70	(0.96	0.61	(0.91)
	15	1.54	(1.43)	1.11	(1.22)	0.94	(1.13)	0.84	(1.06)	0.74	(1.01)
	30	1.81	(1.59)	1.30	(1.36)	1.12	(1.26)	1.00	(1.19)	0.90	(1.13)
Central	1	2.18	(1.70)	1.63	(1.44)	1.38	(1.32)	1.19	(1.23)	1.00	(1.14)
	3	2.35	(1.83)	1.80	(1.56)	1.54	(1.42)	1.34	(1.30)	1.14	(1.17)
	7	2.53	(1.92	1.97	(1.67)	1.70	(1.53)	1.50	(1.42)	1.30	(1.29)
	15	2.76	(2.02)	2.16	(1.78)	1.88	(1.65)	1.68	(1.54)	1.48	(1.42)
	30	3.14	(2.17)	2.44	(1.93)	2.13	(1.80)	1.91	(1.70)	1.70	(1.59)
Southeastern	1	0.97	(1.31)	0.64	(1.02)	0.51	(0.89)	0.43	(0.80)	0.37	(0.72)
	3	1.08	(1.49)	0.74	(1.22)	0.62	(1.10)	0.54	(1.02)	0.48	(0.95)
	7	1.21	(1.61)	0.84	(1.33)	0.71	(1.21)	0.63	(1.13)	0.56	(1.06)
	15	1.32	(1.65)	0.92	(1.38)	0.78	(1.27)	0.70	(1.18)	0.63	(1.11)
	30	1.13	(1.05)	0.72	(0.80)	0.59	(0.70)	0.51	(0.64)	0.46	(0.60

3.3.3 Seasonal

The $7Q_{20}$ values were also determined for each month. The resulting analyses are summarized in Appendices B-F. It is evident from the summary tables that many of the lowest of the $7Q_{20}$ generally take place in the summer months.

3.4 Flow Duration

3.4.1 Annual

Flow duration tables and curves were produced to summarize the percentage of time the flow was greater than or equal to the given value. Flow duration curves for all stations are given in Appendices B to F. An example table is given in Table 5. The first column "Per" refers to the percentage of the period of record that the tabulated flow was equalled or exceeded (all flows are in m^3/s). The annual flow duration curve values are listed in column 2 for the percentage summarized in column 1. Therefore, the largest daily flow recorded for this station up to 1986 is 702 m^3/s, found in the 1st row at 0 percent. More significantly for this study are the low flows summarized in the later section of the table which have been exceeded 90, 95 and 100 percent of the time for the period of record.

The 50 percent value (114 m^3/s) refers to the median daily flow for the period of record of the flow series and can be compared to the mean value 145 m^3/s summarized in the last row of the table. The annual flow duration curve is graphically depicted in Figure 2, which corresponds to the numerical values summarized in columns 1 and 2.

TABLE 5

EXAMPLE SUMMARY OF FLOW DURATION ANALYSIS

SUMMARY TABLE FROM FLOW DURATION ANALYSIS 02HK004 TRENT RIVER AT GLEN ROSS

YEARS OF RECORD: 23 STATION AREA: 12000 km^2

PER	ANNUAL	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
0	702.000	425.000	681.000	637.000	702.000	515.000	328.000	391.000	198.000	340.000	385.000	425.000	439.000
1	518.000	393.000	400.000	549.000	654.000	490.000	273.000	374.000	163.000	284.000	378.000	413.000	425.000
2	489.000	365.000	344.000	530.000	618.000	473.000	255.000	289.000	128.000	240.000	337.000	399.000	381.000
3	459.000	340.000	337.000	515.000	584.000	464.000	225.000	183.000	110.000	225.000	323.000	351.000	375.000
4	435.000	319.000	323.000	501.000	558.000	459.000	220.000	171.000	108.000	198.000	309.000	337.000	364.000
5	418.000	294.000	270.000	491.000	550.000	439.000	213.000	164.000	99.100	189.000	272.000	335.000	337.000
6	398.000	270.000	253.000	477.000	534.000	434.000	205.000	161.000	98.300	167.000	213.000	311.000	316.000
7	379.000	266.000	244.000	458.000	528.000	431.000	198.000	156.000	93.400	150.000	203.000	279.000	306.000
8	357.000	259.000	234.000	442.000	521.000	427.000	191.000	152.000	90.800	135.000	197.000	261.000	300.000
9	337.000	253.000	230.000	425.000	518.000	418.000	187.000	148.000	87.300	129.000	189.000	252.000	289.000
10	328.000	250.000	229.000	419.000	513.000	408.000	183.000	138.000	84.800	128.000	181.000	249.000	279.000
11	300.000	246.000	228.000	410.000	510.000	399.000	181.000	127.000	81.300	117.000	175.000	246.000	274.000
12	290.000	243.000	222.000	406.000	504.000	382.000	179.000	121.000	77.500	105.000	167.000	241.000	272.000
13	272.000	240.000	217.000	397.000	499.000	378.000	174.000	112.000	74.200	93.400	159.000	238.000	270.000
14	263.000	238.000	213.000	388.000	498.000	367.000	171.000	108.000	70.700	91.200	154.000	233.000	268.000
15	255.000	234.000	209.000	374.000	496.000	354.000	166.000	103.000	68.500	88.800	148.000	229.000	266.000
16	247.000	233.000	207.000	357.000	490.000	340.000	164.000	99.100	66.000	86.400	146.000	223.000	265.000
17	237.000	232.000	203.000	351.000	487.000	334.000	161.000	98.300	64.000	83.500	140.000	219.000	262.000
18	230.000	228.000	202.000	347.000	481.000	328.000	156.000	92.000	61.800	81.000	135.000	215.000	260.000
19	224.000	227.000	198.000	341.000	475.000	323.000	153.000	87.000	60.900	78.200	133.000	211.000	258.000
20	219.000	224.000	195.000	331.000	470.000	300.000	149.000	81.600	59.700	75.900	130.000	208.000	254.000
21	213.000	222.000	190.000	321.000	467.000	292.000	142.000	78.200	58.000	74.800	127.000	205.000	252.000
22	208.000	221.000	187.000	316.000	467.000	283.000	136.000	75.300	56.900	73.800	124.000	201.000	246.000
23	202.000	218.000	184.000	311.000	464.000	270.000	133.000	73.000	55.400	72.300	121.000	198.000	237.000
24	198.000	216.000	183.000	303.000	460.000	264.000	130.000	70.500	53.800	69.700	119.000	193.000	227.000
25	193.000	211.000	181.000	297.000	458.000	260.000	126.000	69.400	52.600	67.100	115.000	189.000	223.000
26	187.000	208.000	180.000	289.000	456.000	250.000	120.000	65.700	50.700	64.900	113.000	187.000	221.000
27	183.000	204.000	178.000	283.000	453.000	242.000	116.000	61.700	50.000	63.400	111.000	184.000	217.000
28	180.000	201.000	175.000	273.000	450.000	235.000	112.000	59.400	47.800	61.200	109.000	181.000	215.000
29	177.000	198.000	174.000	268.000	447.000	228.000	111.000	58.000	47.000	58.900	106.000	179.000	213.000
30	173.000	193.000	171.000	265.000	445.000	224.000	109.000	56.900	46.400	58.600	104.000	178.000	212.000
31	169.000	189.000	170.000	262.000	439.000	221.000	106.000	54.900	45.800	57.500	102.000	177.000	206.000
32	165.000	186.000	169.000	256.000	436.000	217.000	104.000	53.800	44.500	56.900	101.000	174.000	204.000
33	162.000	183.000	166.000	247.000	430.000	215.000	102.000	52.400	44.100	56.600	99.800	172.000	202.000
34	159.000	182.000	165.000	237.000	429.000	213.000	99.100	50.700	43.000	55.200	98.500	170.000	200.000
35	155.000	178.000	163.000	230.000	422.000	210.000	95.700	49.900	42.500	54.400	97.400	168.000	199.000
36	152.000	177.000	162.000	227.000	421.000	208.000	91.800	48.100	42.000	54.100	96.300	166.000	194.000
37	149.000	174.000	160.000	225.000	417.000	207.000	90.000	46.400	41.600	53.500	94.000	163.000	192.000
38	146.000	172.000	159.000	219.000	411.000	204.000	88.100	45.400	40.000	53.000	91.200	159.000	190.000
39	143.000	170.000	157.000	212.000	408.000	201.000	87.200	44.500	39.400	51.800	89.200	157.000	189.000
40	139.000	168.000	156.000	208.000	405.000	197.000	85.000	43.800	38.800	51.500	86.900	154.000	186.000
41	136.000	166.000	153.000	203.000	398.000	195.000	84.000	43.200	38.200	51.000	85.000	152.000	183.000
42	133.000	163.000	150.000	199.000	396.000	193.000	81.600	42.200	37.200	50.100	84.100	150.000	182.000
43	130.000	161.000	148.000	193.000	391.000	189.000	80.500	41.300	36.800	49.800	83.500	147.000	180.000
44	128.000	159.000	147.000	189.000	386.000	184.000	79.400	40.500	36.300	49.200	82.400	146.000	178.000
45	126.000	155.000	144.000	186.000	383.000	181.000	77.600	39.600	35.700	48.700	81.700	143.000	177.000
46	123.000	153.000	144.000	183.000	381.000	178.000	77.300	39.100	35.400	47.700	80.400	142.000	175.000
47	121.000	151.000	142.000	179.000	377.000	173.000	76.200	38.200	34.800	46.400	79.300	137.000	173.000
48	118.000	149.000	140.000	169.000	372.000	171.000	74.300	37.700	34.300	45.700	78.200	132.000	170.000
49	116.000	148.000	139.000	165.000	365.000	170.000	73.100	37.100	33.700	44.300	75.900	127.000	165.000

TABLE 5 (con't)

SUMMARY TABLE FROM FLOW DURATION ANALYSIS 02HK004 TRENT RIVER AT GLEN ROSS

YEARS OF RECORD: 23 STATION AREA: 12000 km^2

PER	ANNUAL	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
50	114.000	146.000	138.000	162.000	357.000	167.000	71.300	36.000	33.100	44.100	74.500	126.000	163.000
51	111.000	143.000	135.000	158.000	349.000	164.000	68.800	35.300	32.700	43.300	73.600	123.000	162.000
52	109.000	141.000	134.000	154.000	345.000	162.000	68.000	34.500	32.300	43.000	71.400	121.000	161.000
53	108.000	140.000	133.000	152.000	340.000	160.000	65.700	33.700	32.300	42.500	69.300	118.000	157.000
54	104.000	139.000	132.000	145.000	337.000	158.000	64.000	33.100	31.900	41.900	67.100	116.000	155.000
55	103.000	138.000	131.000	142.000	331.000	156.000	62.300	32.800	31.700	41.300	66.000	115.000	153.000
56	100.000	136.000	130.000	137.000	326.000	154.000	60.900	32.300	31.100	41.100	65.100	114.000	152.000
57	97.700	133.000	129.000	136.000	315.000	151.000	59.700	32.000	31.100	40.500	63.100	111.000	151.000
58	95.700	133.000	128.000	135.000	306.000	149.000	57.200	31.700	30.800	39.900	61.700	109.000	149.000
59	93.000	131.000	127.000	132.000	303.000	148.000	55.500	31.100	30.600	38.500	60.300	107.000	147.000
60	90.600	130.000	126.000	131.000	301.000	146.000	54.700	30.900	30.300	37.900	59.500	107.000	145.000
61	87.500	129.000	125.000	130.000	294.000	145.000	53.800	30.300	29.900	37.400	58.700	104.000	144.000
62	85.000	127.000	125.000	128.000	289.000	144.000	53.400	30.000	29.400	36.700	57.800	103.000	142.000
63	82.700	127.000	123.000	128.000	283.000	141.000	51.600	29.500	29.400	36.500	57.200	99.100	139.000
64	80.100	125.000	122.000	127.000	273.000	140.000	51.000	29.000	29.200	36.200	56.000	97.100	136.000
65	77.900	125.000	120.000	126.000	265.000	137.000	50.400	28.900	28.600	35.700	55.500	94.600	135.000
66	75.300	123.000	120.000	125.000	262.000	137.000	49.300	28.500	28.300	35.400	54.600	92.800	133.000
67	72.800	122.000	119.000	123.000	255.000	134.000	47.800	28.100	28.000	35.000	53.500	90.900	131.000
68	69.400	120.000	118.000	121.000	248.000	133.000	47.000	27.600	27.600	34.500	52.700	89.200	129.000
69	65.900	120.000	117.000	120.000	245.000	129.000	46.400	27.000	27.200	34.300	52.100	88.100	126.000
70	62.600	119.000	116.000	118.000	238.000	126.000	45.300	26.500	27.000	34.300	51.500	83.800	125.000
71	59.700	119.000	114.000	117.000	233.000	123.000	44.500	26.200	26.700	33.700	50.700	82.100	123.000
72	57.500	118.000	113.000	116.000	227.000	121.000	43.200	25.900	26.100	33.400	50.100	79.300	121.000
73	55.500	116.000	112.000	114.000	223.000	120.000	41.900	25.400	25.700	32.800	49.600	76.200	119.000
74	53.500	116.000	110.000	114.000	219.000	115.000	41.100	25.200	25.500	32.300	48.100	73.800	117.000
75	51.700	115.000	108.000	112.000	212.000	111.000	40.200	24.900	25.500	32.200	46.900	72.200	116.000
76	50.400	114.000	107.000	111.000	204.000	109.000	39.800	24.500	25.100	31.700	46.200	69.800	115.000
77	48.400	112.000	105.000	108.000	198.000	106.000	38.400	24.000	24.600	31.300	45.000	67.100	114.000
78	46.400	110.000	105.000	106.000	193.000	103.000	37.400	23.400	24.400	31.100	43.600	66.000	112.000
79	44.500	108.000	103.000	106.000	184.000	102.000	36.600	22.500	24.000	30.900	42.200	62.500	111.000
80	43.000	107.000	101.000	105.000	182.000	98.800	36.000	21.400	24.000	30.600	40.800	59.400	110.000
81	41.100	106.000	99.700	104.000	178.000	95.100	35.400	21.000	24.000	29.700	39.400	57.100	108.000
82	39.400	105.000	98.500	103.000	174.000	92.000	34.500	20.100	23.700	29.400	37.900	55.500	106.000
83	37.700	104.000	97.000	102.000	168.000	88.200	33.400	19.900	23.400	28.600	37.400	53.200	103.000
84	36.300	103.000	96.800	99.500	161.000	86.400	32.300	19.700	23.200	28.000	36.500	51.800	103.000
85	34.800	102.000	95.200	97.400	157.000	83.500	31.100	19.500	22.500	27.400	33.700	50.100	101.000
86	33.600	99.100	94.600	96.300	155.000	80.100	30.300	19.300	22.400	26.700	33.100	48.700	100.000
87	32.300	97.500	93.400	96.300	151.000	78.100	28.600	19.000	22.100	26.200	32.600	45.000	98.300
88	31.100	95.800	92.100	92.900	148.000	75.900	27.900	18.500	21.600	25.700	30.900	43.600	96.300
89	30.300	92.000	90.800	89.500	142.000	74.200	26.700	17.800	20.500	25.100	30.300	42.500	94.600
90	29.200	91.700	87.800	86.400	129.000	69.700	25.400	17.500	19.800	24.500	29.700	40.500	93.400
91	28.200	85.000	85.000	85.100	121.000	68.200	24.500	17.200	19.100	24.400	29.700	38.800	90.900
92	27.000	83.300	83.300	84.100	112.000	64.800	23.400	16.700	18.000	24.100	29.400	35.400	88.900
93	25.700	83.000	82.400	81.300	108.000	61.400	21.400	15.900	16.400	23.400	29.200	33.700	82.400
94	24.500	79.300	77.900	79.300	103.000	59.700	19.400	15.700	15.500	23.000	28.600	29.200	79.000
95	23.500	79.300	72.500	76.200	95.400	57.500	18.400	15.200	15.200	22.800	28.200	27.700	73.300
96	22.200	75.300	54.100	69.400	85.200	46.200	17.600	14.800	14.700	22.500	27.700	24.500	66.500
97	19.700	71.400	51.900	54.100	81.000	41.100	16.700	14.400	13.800	21.700	26.900	23.300	39.600
98	17.500	66.300	50.000	51.000	62.600	32.000	16.000	13.700	12.800	21.200	25.200	11.500	37.100
99	15.000	54.100	47.600	49.400	58.900	25.100	14.800	12.300	10.700	19.100	21.700	11.000	33.700
100	10.600	47.600	20.800	28.600	46.400	21.300	13.100	11.400	10.600	18.200	15.000	10.600	31.700
MEAN	145.088	164.599	154.392	213.784	339.233	200.326	89.653	59.528	43.800	61.885	95.104	141.925	179.096

3.4.2 Seasonal

The flow duration values were also determined and tabulated for monthly flows. Appropriate summaries for all stations are given in Appendices B to F. This is also shown in Table 5 in the example for Station 02HK004, Trent River at Glen Ross.

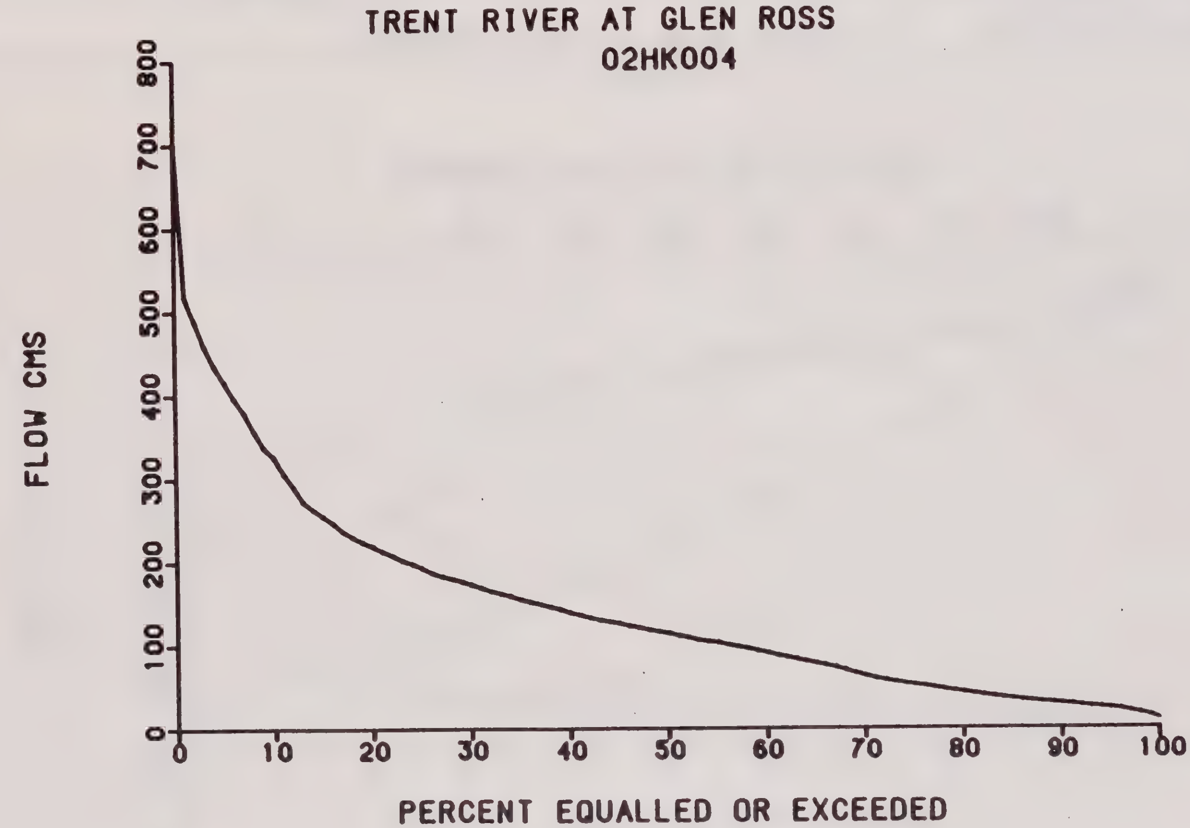
The seasonal duration curves were not graphically produced for each station. However an example plot for Station 02HK004 demonstrates how the tabulated values could be used to plot monthly curves and provide a comparison to the annual curve (see Figures 3, 4 and 5).

3.5 Maps

Selected low flow characteristics were summarized on maps for each region. The stations are located at the point of discharge measurement and the selected data is summarized in an information box, the format of which is depicted in Figure 6.

The stations are identified by the 7 digit Water Survey Station Number and this is followed by a regulation code. A code "R" indicates that data collected at the station is affected by regulation; the code "N" means the station data are natural or non-regulated. The symbols $7Q_2$, etc. refer to the average minimum consecutive 7-day flow (m^3/s) with a recurrence interval of 2, 5, 10 and 20 years, followed by the minimum one day flow and the period of record for the station. The values shown on the right are the flows (m^3/s) equalled or exceeded for the available period of record 5, 50, 75, 95, and 99 percent of the time. The symbol AREA refers to the station drainage area in km^2.

Station names are listed along with the station numbers for identification purposes, on the map for each region.



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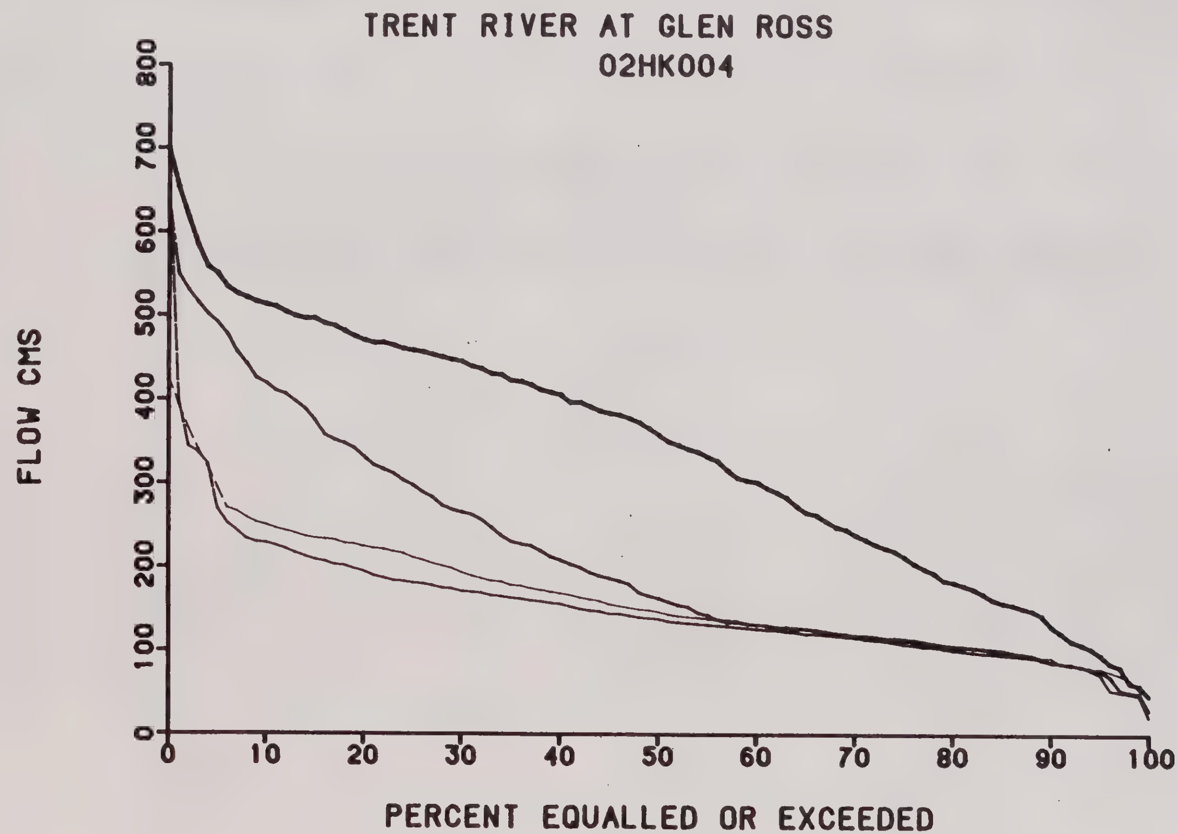
EXAMPLE OF
ANNUAL
FLOW DURATION CURVE

FIGURE 2



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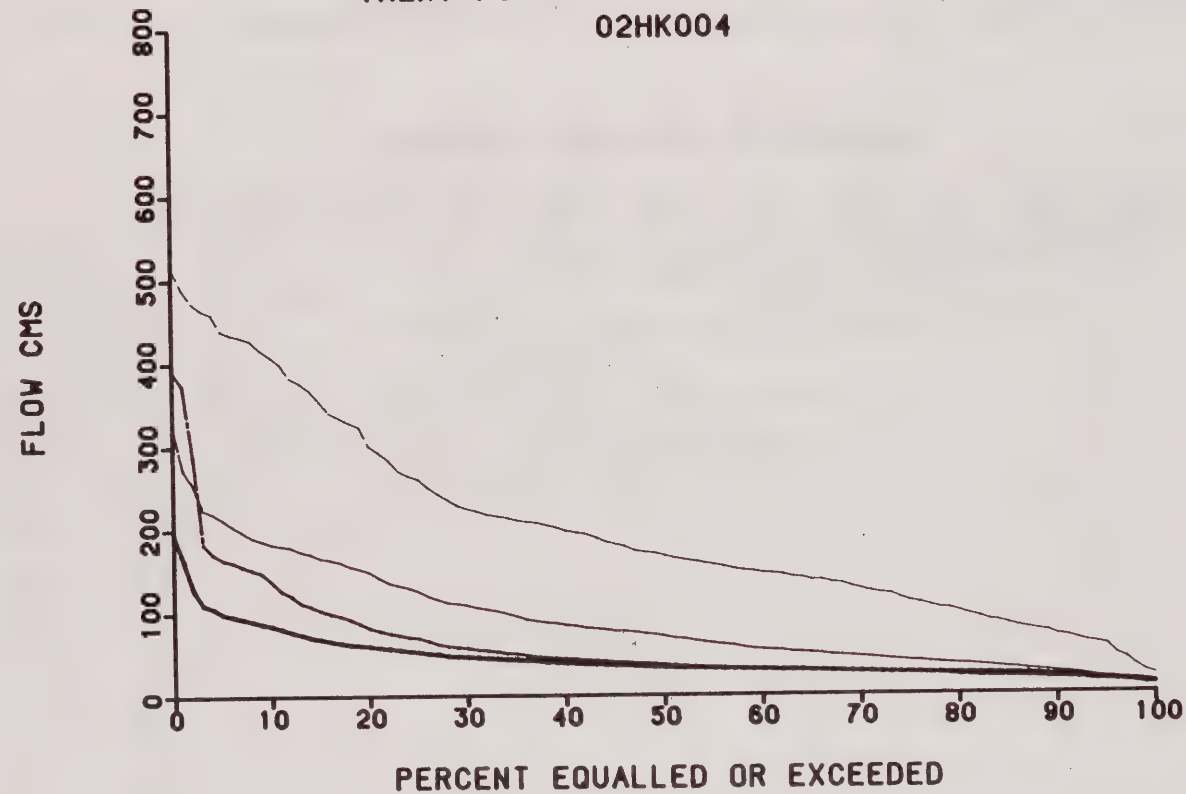
LEGEND

JANUARY
FEBRUARY
MARCH
APRIL

EXAMPLE OF SEASONAL
FLOW DURATION CURVE

FIGURE 3

TRENT RIVER AT GLEN ROSS
02HK004



LEGEND

MAY
JUNE
JULY
AUGUST

EXAMPLE OF SEASONAL
FLOW DURATION CURVE

FIGURE 4

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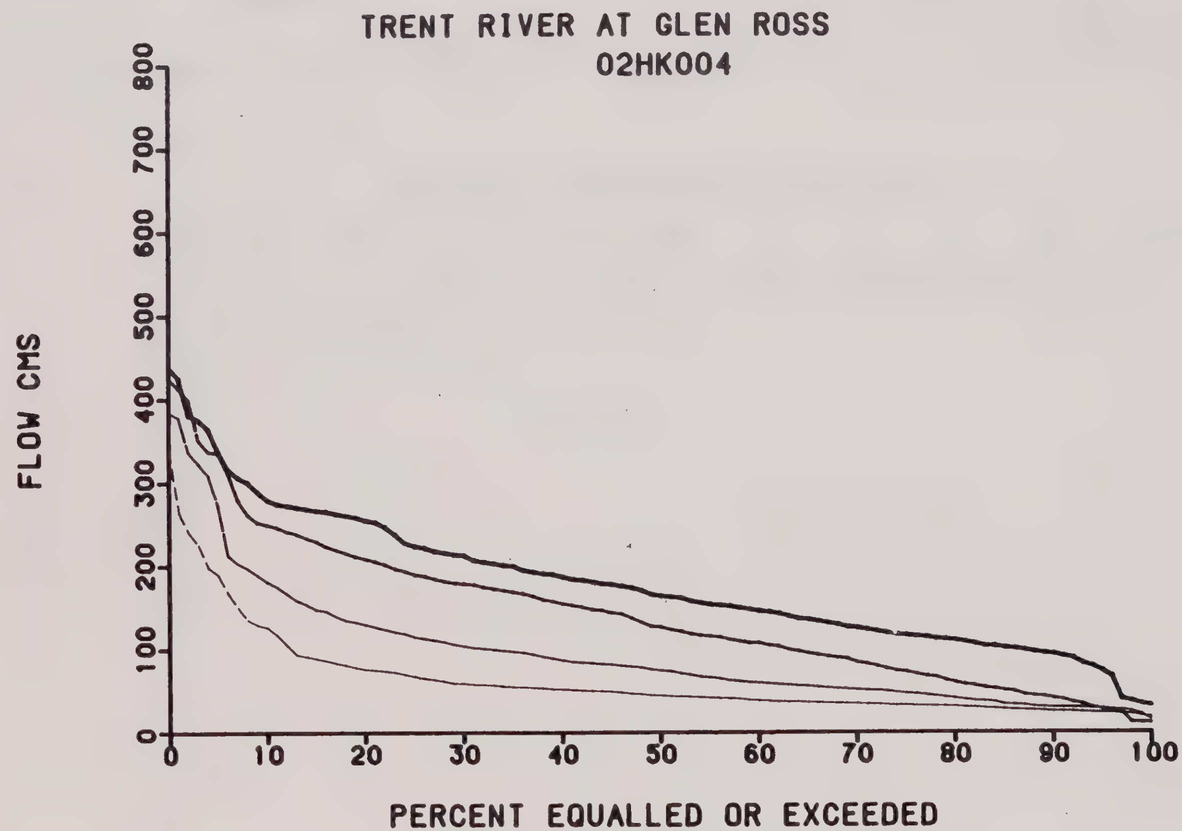

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LEGEND

SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

EXAMPLE OF SEASONAL
FLOW DURATION CURVE

FIGURE 5

7Q2	5%DUR
7Q5	50%DUR
7Q10	75%DUR
7Q20	95%DUR
MIN DAY	99%DUR
PERIOD	AREA
STATION #	RC

7Q20	7-DAY AVERAGE LOW-FLOW WITH RECURRENCE OF 20 YEARS (m^3/s)
95% DUR	FLOW EXCEEDED 95% OF RECORD (m^3/s)
PERIOD	PERIOD OF RECORD (years)
AREA	DRAINAGE AREA (km^2)
MIN DAY	LOWEST 1 DAY AVERAGE FLOW (m^3/s)
STATION #	WSC STATION IDENTIFICATION
RC	REGULATION CODE

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STATION INFORMATION LEGEND

FIGURE 6

A second map summarizes the above noted low flow characteristics expressed as $l/s/km^2$. It may be possible to refer to watersheds with similar unit runoff rates as a means of providing preliminary low flow estimates for ungauged watersheds. However, the limitations of area proration should be recognized. For example, a preliminary Low Flow Regionalization Study for Southwestern and West Central Ontario Region (Cumming Cockburn Limited, 1988) has found that other significant watershed parameters enter into the determination of low flows. Additional investigations are required in order to refine estimating techniques for ungauged watersheds.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

1. The analysis of non-parametric test results indicate that the available data base of extreme low flows may exhibit some trend and dependence with some possibility of non-random characteristics. Therefore, some degree of caution should be used when applying the results of this study.

2. The Gumbel Extreme Value Distribution was found to adequately fit the majority of available low flow series for various low flow durations. However, for a number of samples with large negative skewness, the 3 PLN Distribution was adopted.

3. Flow duration analyses were successfully undertaken both on an annual and monthly basis.

4. Extreme value analysis were undertaken on an annual basis for 344 stations and on a monthly basis for 330 stations using the LFA program. Graphical analyses were undertaken for the remainder of the stations.

5. It was found that area average low flows are consistently higher than the Provincial average in the Northwestern, Northeastern and Central Regions and consistently lower in the Southwestern/West Central and Southeastern Regions.

6. A map summarizing the following low flow characteristics was produced for each region:

   - 7 day average extreme values for the 2, 5, 10 and 20 year recurrence intervals
   - flow duration values which were equalled or exceeded over the available period 5, 50, 75, 95 and 99 percent of the time

A second map was also produced for each region which summarized the above low flow characteristics expressed as $l/s/km^2$.

7. Users referring to the analysis results for regulated stations should investigate the effects of regulation on low flows in more detail.

4.2 Recommendations

1. Further investigation should be undertaken to confirm the applicability of available non-parametric tests for low flow series.

2. The possibility of effects of cyclic changes in groundwater regime or climatic changes on low flows should be examined in future investigations.

3. Additional investigations are required in order to refine low flow estimating techniques for ungauged watersheds for each region.

4. Maps summarizing monthly $7Q_{20}$ low flow characteristics should be produced for each region. This would be useful when undertaking seasonal low flow analyses to facilitate seasonal analyses.

5. Discharge data are collected continuously by the Water Survey of Canada at each station. Data analysis and management technique are now available which would allow efficient updating of the present analyses on a frequent basis. In our opinion, the low flow analyses should be updated every three years in order to provide reasonably accurate information for investigations requiring low flow information.

5.0 REFERENCES

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APPENDIX A

GENERAL APPENDICES

LOW FLOW CHARACTERISTICS IN ONTARIO

Report prepared for:
Water Resources Branch

Report prepared by:
CUMMING COCKBURN LIMITED
145 Sparks Avenue
Willowdale, Ontario
M2H 2S5

APRIL 1990

RECYCLABLE

APPENDIX A.1
EXTREME VALUE ANALYSIS

APPENDIX A
LOW FLOW CHARACTERISTICS IN ONTARIO

TABLE OF CONTENTS

APPENDIX A.1

EXTREME VALUE ANALYSIS

Introduction

Statistical distributions allow estimates of probability of exceedance of events to be made by analytical techniques. Various methods are available, and a good discussion is given by McMahon and Mein (ref 9).

At a gauged location, average low flows can be determined for selected durations of time for each year of record. For example, the corresponding minimum average consecutive 15-day low flow can be determined for each annual record. The series of 15-day average annual low flows can then be ranked lowest to highest and an extreme value analysis undertaken using a theoretical distribution.

The Gumbel Extreme Value Distribution is commonly used for fitting low flow frequency curves to the available data.

The Gumbel Type III Distribution

This is a variation of Fisher and Tippett's third asymnptotic distribution of extreme values and is sometimes referred to as the Weibull distribution. In view of his many contributions it is often referrred to in hydrology as the Gumbell II. The probability density function is:

$$\phi(x) = \frac{a}{u - e} \left\{ \frac{x - e}{u - e} \right\}^{a-1} \exp \left[- \left\{ \frac{x - e}{u - e} \right\}^{a} \right] \qquad (1)$$

where e is the lower bound parameter

u is the characteristic drought

and a is the shape parameter

Various methods are available for determining the distribution parameters for a particular data set. See references 2 and 6 for example.

The Probability Function

The density function is integrable and gives the distribution function

$$F(x) = 1 - \exp\left[-\left\{\frac{x-e}{u-e}\right\}^{a}\right] \tag{2}$$

which gives the probability of non-exceedance of x.
Since it is more common to require x for a given probability of non-exceedance, a simple re-arrangement gives

$$x = e + (u - e)\left\{-\ln\left[1 - F(x)\right]^{1/a}\right\} \tag{3}$$

There are occasions when the sample series of low flows can have a large negative coefficient of skewness, and since the Gumbel Type III distribution cannot have a skewness of less than -1.14, then the distribution cannot be fitted.

There are insuffucient natural samples available with such low skewness to make a firm choice of an alternative treatment, but from the few available, it was found that the negatively skewed three-parameter lognormal distribution provided an acceptable alternative.

If $y = \ln(a-x)$ is normally distributed, then the probability density function of x is given by

$$\phi(x) = \frac{1}{(a-x)\sigma\sqrt{2\Pi}} \exp\left\{-\frac{1}{2\sigma^2}\left[\ln(a-x) - m\right]^2\right\} \tag{4}$$

where m and σ are respectively the mean and standard deviation of the series $\ln(a-x)$ and a is an lower boundary parameter. This form of the distribution can only have negative skewness. The equation in the form $\ln(x-a)$ is for distributions with positive skewness.

Taking moments, re-arranging and replacing them by their sample estimates gives:

$$k^3 + 3k - g_1 = 0 \qquad (36a) \quad (5)$$

and after solving for k

$$\hat{a} = x - s/k \qquad (37a) \quad (6)$$

$$\hat{m} = \ln(-s/k) - 1/2\ln(k^2+1) \qquad (38a) \quad (7)$$

$$\sigma^2 = \ln(k2+1) \qquad (39a) \quad (8)$$

Thus, the distribution is completely defined and the T-year low flows can be computed from:

$$Q_T = \hat{a} - \exp(\hat{m}\ \sigma t) \qquad (9)$$

Additional details are discussed in the user's manual.

Source: Condie, R., L. C. Cheng
"Low Flow Frequency Analysis - Program LOFLOW",
Water Resources Branch, Inland Waters Directorate
Environment Canada, Ottawa, 1987

APPENDIX A.2
FLOW DURATION ANALYSIS

APPENDIX A.2
FLOW DURATION ANALYSIS

A flow duration curve is a plot of the flow of a stream against the percent of time the indicated flow was equalled or exceeded during the period covered by the available flow data. This curve is extremely useful for hydro power studies and for characterizing the local streamflow regime.

An empirical procedure was used to analyse each sample discharge record. Flow duration curves are derived by rearranging the available daily or monthly flow data in order of magnitude. The total time period represents 100% of the time. Therefore, by definition of the procedure used here, the largest value is exceeded 0 percent of the time and the smallest value is exceeded 100% of the time.

The flow duration curve represents the percent of time that a specific discharge occurs at that location. However, the curve does not indicate the period of time in the year when the flow is less than or equal to the selected value. Therefore, in some instances, it is also useful to develop flow duration curves on a monthly basis, that is, all data for the month of January over the entire period of record is analysed independently to produce a flow duration curve representative of flow conditions in January.

Single station flow duration analyses and corresponding monthly flow duration curves have been determined at all relevant stream and flow locations across the Province.

APPENDIX A.3
NON-PARAMETRIC TESTS FOR
INDEPENDENCE, TREND AND RANDOMNESS

APPENDIX A.3
NONPARAMETRIC TESTS FOR INDEPENDENCE, TREND AND RANDOMNESS

A.3.1 Test Description

This appendix briefly summarizes the functions evaluated in the package and gives the methods used to determine their statistical significance. Statistical tables are provided for ease of reference.

A.3.1.1 Introduction

Any statistical test of significance will generally be made using the following steps:

a) State the null hyposthesis, H_0. For instance in split sample tests, the null hypothesis may be that there is no difference between the sample means.

b) Choose a significance level, a.

c) Choose an appropriate statistical test. In this program all tests are nonparametric.

d) Compute the test statistic.

e) The sampling distribution of the test statistic is known and has been tabulated, and the chosen significance level then defines the region of rejection.

f) If the computed test statistic lies in the region of rejection, then the null hypothesis is rejected.

Consider now the four tests in this program.

A.3.1.2 The Spearman Rank Order Serial Correlation Coefficient for Independence

If the series Q_i with i ranging from 1 to N is put in chronological order, two time series are formed and their respective ranks computed:

Q_1, Q_2 ....Q_N-1 by x_i, the rank of Q_i; i=1; N-1
and Q_2, Q_3 ....Q_N by y_i, the rank of Q_i; i=2, N

then Spearman rank order serial correlation coefficient is

$$S_1 = \tfrac{1}{2}\,(\Sigma x_i^2 + \Sigma y_i^2 - \Sigma d_i^2)\,(\Sigma x_i^2\,\Sigma y_i^2)^{-\frac{1}{2}} \qquad (1)$$

where $\Sigma x_i^2 = (m^3-m)/12 - \Sigma T_x$

$\Sigma y_i^2 = (m^3-m)/12 - \Sigma T_y$

d_i is the difference in rank between x_i and y_i

$m = N-1$

and the summations are over the m pairs of x_i, y_i.

Ignoring for the moment the terms in T and putting them at zero, equation (a) becomes

$$S_1 = 1-(6\Sigma d_i^2)\,(m^3-m) \qquad (2)$$

the more familiar form of the Spearman rank correlation coefficient.

The terms in T adjust for tied ranks and are computed as follows. If for instance three observations in the x series were tied for ranks 17, 18, and 19 then each observation is given the rank 18; if two were tied for ranks 24 and 25, then each is ranked 24.5.

For each tied set, T is computed from

$$T_x = (J^3 - J)/12$$

where J is the number of observations tied at a give rank. ΣT_x and ΣT_y are defined by the extension of the foregoing. When N is 10 or greater, then the function

$$t = S_1 \left[(m-2)/(1-S_1^2)\right]^{1/2} \tag{3}$$

is distributed like Student's t with m-2 degrees of freedom. A one-tail test must be used.

A.3.1.3 The Spearman Rank Order Correlation Coefficient Test for Trend

If the series Q_i with i ranging from 1 to N is put in chronological order, ranks assigned and denoting the series

Q_1, Q_2 ....Q_N by y_i, the rank of Q_i
and 1, 2, ...N by x_i, the sequential order of Q_i

then the Spearman rank order correlation coefficient r_s is calculated as in equation 1, except that m = N, $T_x = 0$, and the summations are taken over the N pairs of x_i, y_i.

For N = 10 or greater, then the function

$$t = r_s \left[(N-2)/(1-r_s^2)\right]^{1/2} \tag{4}$$

is distributed like Student's t with N-2 degrees of freedom. The null hypothesis is that there is no trend, either upward or downward with time, and so a two-tail test is used.

A.3.1.4 Runs Above and Below the Median for General Randomness

This randomness test is based on the order or sequence in which the individual scores or observations were obtained. Actually, the test is based on the number of runs which a sample exhibits.

A run is defined as a succession of identical symbols which are followed and preceded by different symbols or by no symbols at all.

The total number of runs in a sample of any given size gives an indication of whether or not the sample is random. If very few runs occur, a time trend or some bunching due to lack of independence is suggested. If a great many runs occur, systematic short-period cyclical fluctuations seem to be influencing the sample.

For example, once the median of the sample has been determined, each observation can be labelled as being above and equal to or below and equal to the median. If "A" represents above and equal to the median and "B" represents below and equal to the median, then a sample may be ordered as

AABBBABBBBAABA

(A run represents a succession of identical symbols). For our example, each run is underscored and numbered consecutively:

$$\underset{1}{\underline{AA}} \quad \underset{2}{\underline{BBB}} \quad \underset{3}{\underline{A}} \quad \underset{4}{\underline{BBBB}} \quad \underset{5}{\underline{AA}} \quad \underset{6}{\underline{B}} \quad \underset{7}{\underline{A}}$$

This sample begins with 2 observations above or equal to the median, followed by a run of 3 observations below or equal to the median, etc.

Seven runs are observed in all: that is, the total number of runs above and below the median RUNAB, is 7. If n_1 represents

the number of events of type A, then $n_1 = 6$. If n_2 denotes the number below the median, type B, then $n_2 = 8$. Thus, the number of observations is equal to $(n_1 + n_2)$.

In order to apply this run test, one must determine n_1, n_2 and RUNAB.

The null hypothesis, H_0, is that the A's and B's occur in random order. The alternate hypothesis, H_1, is that the order of the A's and B's deviates from randomness.

When either n_1 or n_2 is greater than 20, the sampling distribution of RUNAB tends to normality with

$$z = \frac{|RUNAB - [(2n_1n_2)/(n_1+n_2)+1]\ |}{\{2n_1n_2(2n_1n_2-n_1-n_2)/[(n_1+n_2)^2(n_1+n_2-1)]^{\frac{1}{2}}} \tag{5}$$

where z is an N(0,1) variate as described in Table A.4. This package uses a region of rejection defined by

z greater than 1.96 for $\alpha = .05$

z greater than 2.575 for $\alpha = .01$

A.3.2 Example of Tests

The non-parametric test referred to in Section 2.3 were performed on all extreme value data sets. The data for the 7-day duration for Station 02BD002 which "failed" the non-parametric tests is tabulated in Table 1 and comparatively the data for Station 02AB009 which passed all the non-parametric tests is given in Table 2. The results of the tests for independence, trend and randomness for both stations are given in Tables 3 and 4 respectively.

Source: Pilon, P.J., R. Condie, K. D. Harvey
"Consolidated Frequency Analysis Program - CFA", July 1985
Water Resources Branch, Inland Waters Directorate,
Environment Canada - Ottawa, 1985

TABLE 1

7 DAY DURATION FLOWS USED
FOR EXTREME VALUE ANALYSIS

SHEBANDOWAN RIVER AT SUNSHINE 02AB009

7 DAY LOW FLOW MEAN DISCH. IN PERIOD JAN 01 DEC 31

STARTING MONTH	YEAR	7 DAY MEAN FLOW	ASCENDING ORDER	RANK	CUMULAT. PROBABIL.	RETURN PERIOD
		(CMS)	(CMS)		(%)	(YEARS)
8	1958	5.2310	2.0900	1	2.05	48.67
1	1959	9.3610	2.2740	2	5.48	18.25
8	1960	2.8910	2.5940	3	8.90	11.23
8	1961	3.7160	2.6590	4	12.33	8.11
10	1962	9.7990	2.8640	5	15.75	6.35
10	1963	3.5100	2.8910	6	19.18	5.21
1	1964	2.2740	3.2360	7	22.60	4.42
8	1965	4.1800	3.3830	8	26.03	3.84
7	1966	2.5940	3.5100	9	29.45	3.40
10	1967	3.6090	3.6090	10	32.88	3.04
1	1968	5.4610	3.7160	11	36.30	2.75
9	1969	4.6560	4.0070	12	39.73	2.52
8	1970	2.8640	4.1800	13	43.15	2.32
3	1971	5.9960	4.6560	14	46.58	2.15
9	1972	5.9010	5.2310	15	50.00	2.00
1	1973	6.1360	5.4270	16	53.42	1.87
8	1974	6.1490	5.4610	17	56.85	1.76
11	1975	6.5970	5.9010	18	60.27	1.66
12	1976	2.0900	5.9570	19	63.70	1.57
2	1977	2.6590	5.9960	20	67.12	1.49
12	1978	7.7360	6.1360	21	70.55	1.42
9	1979	4.0070	6.1490	22	73.97	1.35
6	1980	3.3830	6.5970	23	77.40	1.29
9	1981	3.2360	6.7060	24	80.82	1.24
2	1982	5.4270	7.7360	25	84.25	1.19
4	1983	10.8860	8.2340	26	87.67	1.14
10	1984	6.7060	9.3610	27	91.10	1.10
1	1985	8.2340	9.7990	28	94.52	1.06
12	1986	5.9570	10.8860	29	97.95	1.02

TABLE 2

7 DAY DURATION FLOWS USED FOR EXTREME VALUE ANALYSIS

MICHIPICOTEN RIVER AT HIGH FALLS 02BD002

7 DAY LOW FLOW MEAN DISCH. IN PERIOD JAN 01 DEC 31

STARTING MONTH	YEAR	7 DAY MEAN FLOW (CMS)	ASCENDING ORDER (CMS)	RANK	CUMULAT. PROBABIL. (%)	RETURN PERIOD (YEARS)
10	1924	17.0000	5.3860	1	1.01	98.67
9	1925	20.9710	9.6090	2	2.70	37.00
4	1926	19.0140	15.2710	3	4.39	22.77
9	1927	25.6430	15.9710	4	6.08	16.44
3	1928	29.7000	17.0000	5	7.77	12.87
9	1933	15.2710	19.0140	6	9.46	10.57
1	1934	21.3140	20.6430	7	11.15	8.97
9	1935	27.3710	20.9710	8	12.84	7.79
12	1936	25.3140	21.1570	9	14.53	6.88
4	1937	23.1000	21.2140	10	16.22	6.17
10	1938	23.0570	21.3140	11	17.91	5.58
8	1939	25.1860	22.7710	12	19.59	5.10
3	1940	25.8000	23.0570	13	21.28	4.70
8	1941	24.2430	23.1000	14	22.97	4.35
7	1942	27.5570	23.5000	15	24.66	4.05
12	1943	25.9430	23.8860	16	26.35	3.79
1	1944	23.8860	24.2430	17	28.04	3.57
3	1945	24.5430	24.5430	18	29.73	3.36
10	1946	26.1570	25.1860	19	31.42	3.18
12	1947	21.1570	25.3140	20	33.11	3.02
10	1948	20.6430	25.6430	21	34.80	2.87
12	1949	23.5000	25.8000	22	36.49	2.74
2	1950	31.1710	25.9430	23	38.18	2.62
9	1951	50.0860	26.1570	24	39.86	2.51
11	1952	44.0570	26.7000	25	41.55	2.41
10	1953	31.1000	27.2000	26	43.24	2.31
11	1954	36.2140	27.3710	27	44.93	2.23
9	1955	21.2140	27.5570	28	46.62	2.14
4	1956	32.2290	27.7000	29	48.31	2.07
7	1957	39.3710	29.7000	30	50.00	2.00
8	1958	31.8000	30.4430	31	51.69	1.93
6	1959	42.4000	30.8710	32	53.38	1.87
10	1960	30.4430	31.1000	33	55.07	1.82
7	1961	41.0000	31.1710	34	56.76	1.76
8	1962	42.1860	31.8000	35	58.45	1.71
11	1963	38.2290	32.2290	36	60.14	1.66
6	1964	30.8710	32.4570	37	61.82	1.62
9	1965	61.0140	34.9000	38	63.51	1.57
10	1966	36.6290	36.2140	39	65.20	1.53
12	1967	48.7430	36.6290	40	66.89	1.49
3	1968	32.4570	38.2290	41	68.58	1.46
9	1969	5.3860	39.3710	42	70.27	1.42
12	1970	51.0430	39.6430	43	71.96	1.39
11	1971	34.9000	39.7570	44	73.65	1.36
5	1972	45.1860	41.0000	45	75.34	1.33
12	1973	58.3000	41.4710	46	77.03	1.30
5	1974	39.7570	42.1860	47	78.72	1.27
11	1975	15.9710	42.4000	48	80.41	1.24
10	1976	22.7710	44.0570	49	82.09	1.22
1	1977	9.6090	45.1860	50	83.78	1.19
10	1978	41.4710	46.4710	51	85.47	1.17
9	1979	53.1430	48.7430	52	87.16	1.15
6	1980	39.6430	50.0860	53	88.85	1.13
3	1981	27.7000	50.2290	54	90.54	1.10
5	1982	26.7000	51.0430	55	92.23	1.08
9	1983	55.1430	53.1430	56	93.92	1.06
10	1984	50.2290	55.1430	57	95.61	1.05
5	1985	46.4710	58.3000	58	97.30	1.03
8	1986	27.2000	61.0140	59	98.99	1.01

TABLE 3

RESULTS OF STATISTICAL TESTS
FOR STATION 02AB009

--- SPEARMAN TEST FOR INDEPENDENCE ---

```
02AB00913007        SHEBANDOWAN RIVER AT SUNSHINE
ANNUAL MINIMUM DAILY FLOW SERIES    58 TO   86  DRAINAGE AREA =  2800.000

SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =   0.068   D.F. =   26
                  CORRESPONDS TO STUDENTS T =   0.347
               CRITICAL T VALUE AT 5% LEVEL =  1.706    NOT SIGNIFICANT
                    -    -    -    -  1%   -   =  2.479    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the serial(lag-one) correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant serial dependence.

--- SPEARMAN TEST FOR TREND ---

```
02AB00913007        SHEBANDOWAN RIVER AT SUNSHINE
ANNUAL MINIMUM DAILY FLOW SERIES    58 TO   86  DRAINAGE AREA =  2800.000

SPEARMAN RANK ORDER CORRELATION COEFF =  -0.227   D.F. =   27
           CORRESPONDS TO STUDENTS T =  -1.209
        CRITICAL T VALUE AT 5% LEVEL = -2.052    NOT SIGNIFICANT
             -    -    -    -  1%   -   = -2.771    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the serial(lag-one) correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant trend.

--- RUN TEST FOR GENERAL RANDOMNESS ---

```
02AB00913007        SHEBANDOWAN RIVER AT SUNSHINE
ANNUAL MINIMUM DAILY FLOW SERIES    58 TO   86  DRAINAGE AREA =  2800.000

THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN(RUNAB) = 11
     THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 14
     THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 14
Range at 5% level of significance: 10. to 20.    NOT SIGNIFICANT
```

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis cannot be rejected. That is, the sample is significantly random.

TABLE 4

RESULTS OF STATISTICAL TESTS
FOR STATION 02AB009

--- SPEARMAN TEST FOR INDEPENDENCE ---

```
02BD00213007        MICHIPICOTEN RIVER AT HIGH FALLS
ANNUAL MINIMUM DAILY FLOW SERIES    24 TO   86  DRAINAGE AREA =  5130.000


SPEARMAN RANK ORDER SERIAL CORRELATION COEFF =   0.456   D.F. =   56
                  CORRESPONDS TO STUDENTS T =   3.839
               CRITICAL T VALUE AT 5% LEVEL =  1.674        SIGNIFICANT
                    -    -    -    - 1%   -   =  2.397        SIGNIFICANT
```

Interpretation: The null hypothesis is that the serial(lag-one) correlation is zero.

At the 1% level of significance, the correlation is significantly different from zero. That is, the data display highly significant serial depedence.

--- SPEARMAN TEST FOR TREND ---

```
02BD00213007        MICHIPICOTEN RIVER AT HIGH FALLS
ANNUAL MINIMUM DAILY FLOW SERIES    24 TO   86  DRAINAGE AREA =  5130.000


SPEARMAN RANK ORDER CORRELATION COEFF =  -0.528   D.F. =   57
           CORRESPONDS TO STUDENTS T =  -4.693
        CRITICAL T VALUE AT 5% LEVEL = -2.003        SIGNIFICANT
            -    -    -    - 1%   -   = -2.667        SIGNIFICANT
```

Interpretation: The null hypothesis is that the serial(lag-one) correlation is zero.

At the 1% level of significance, the correlation is significantly different from zero. That is the data display highly significant trend.

--- RUN TEST FOR GENERAL RANDOMNESS ---

```
02BD00213007        MICHIPICOTEN RIVER AT HIGH FALLS
ANNUAL MINIMUM DAILY FLOW SERIES    24 TO   86  DRAINAGE AREA =  5130.000

THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN(RUNAB) = 11
     THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 29
     THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 29
```

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)

For this test, Z =   5.034

```
Critical Z value at the 5% level = 1.960              SIGNIFICANT
Critical Z value at the 1% level = 2.575              SIGNIFICANT
```

Interpretation: The null hypothesis is that the data are random.

At the 1% level of significance, the null hypothesis can be rejected. That is, the sample is not significantly random.

A.3.3 Graphical Representation

Graphical procedures are available within the LFA (Pilon, Jackson, 1987) program which visually depict some of the results of the non-parametric tests as shown in figures 1 to 6.

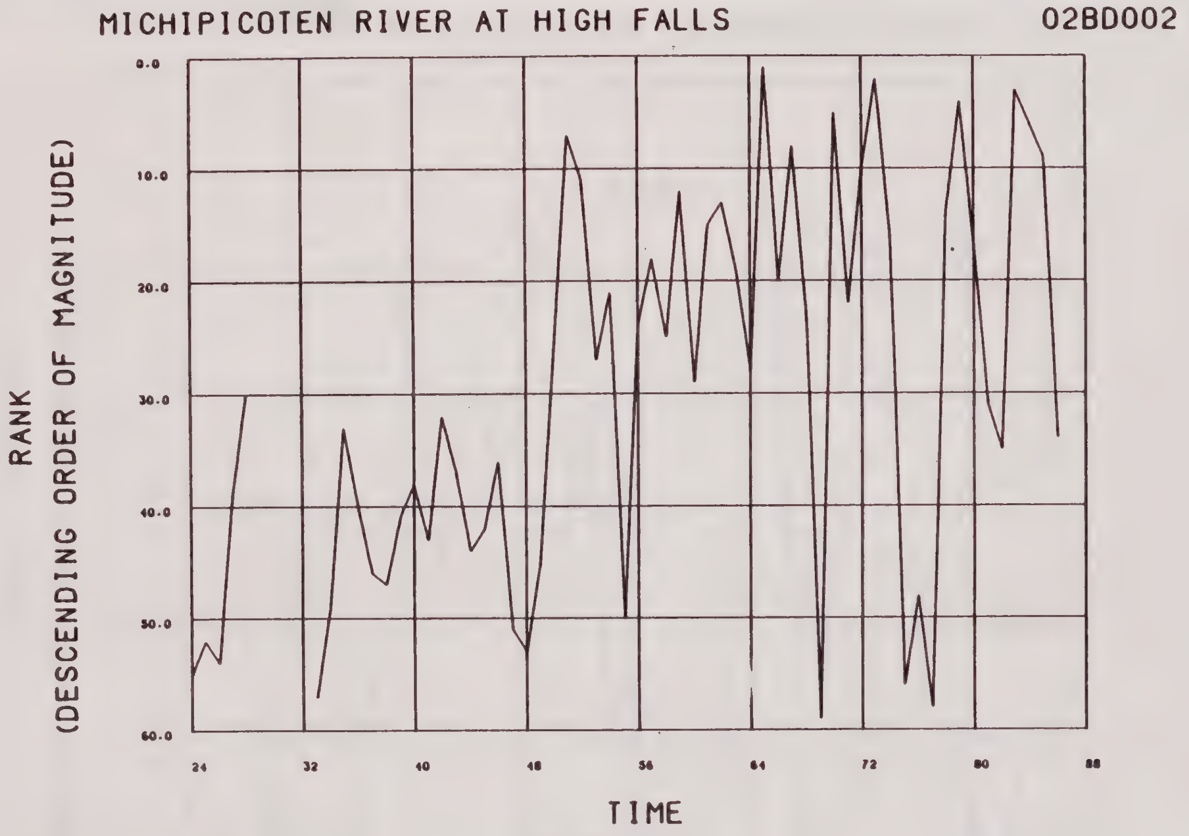
Figures 1 and 2 show that there is an apparent trend for Station 02BD002 when compared with the rank versus time graph of Figure 2. These results correspond to the statistical test results. The increase in low flows as a function of time is very apparent for the data for Station 02BD002 (see Figure 3) when compared to the data from Station 02AB009 shown in Figure 4. Figures 5 and 6 graphically depict the probability density function by displaying a histogram of the number of occurrences of between ranges of low flows. It can be seen that both stations are positively skewed for the 7-day duration data.

A.3.4 Summary of Tests Results

Test results are summarized by region for significant levels of 1% and 5% in appendices B to F, Section 2.0. It can be seen from the summary tables (Tables 2 to 6) that the data for stations in the Central Region are random at the 1% level (refer to Table 2).

All other test results indicate that a large number of the data sets "fail" the non-parametric test. This could indicate some dependence, trend and non-randomness. Hence, some degree of caution should be used when applying the results of this study.

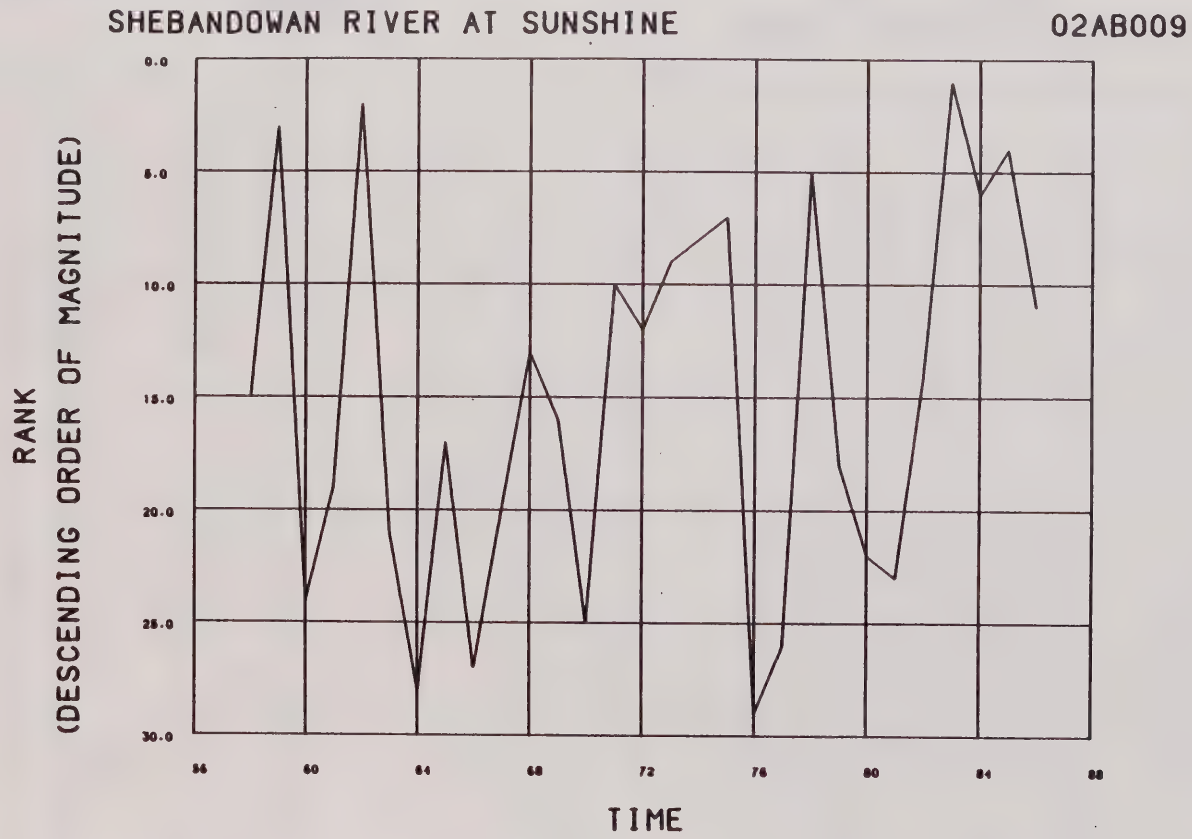
To examine effects of length of record and regulation, the analysis was completed using criteria of $\geq$20 years of record, <20 years of record and regulated vs. non-regulated station data.



Cumming Cockburn Limited
Consulting Engineers and Planners

RANK VERSUS TIME
1924 - 1986

FIGURE 1



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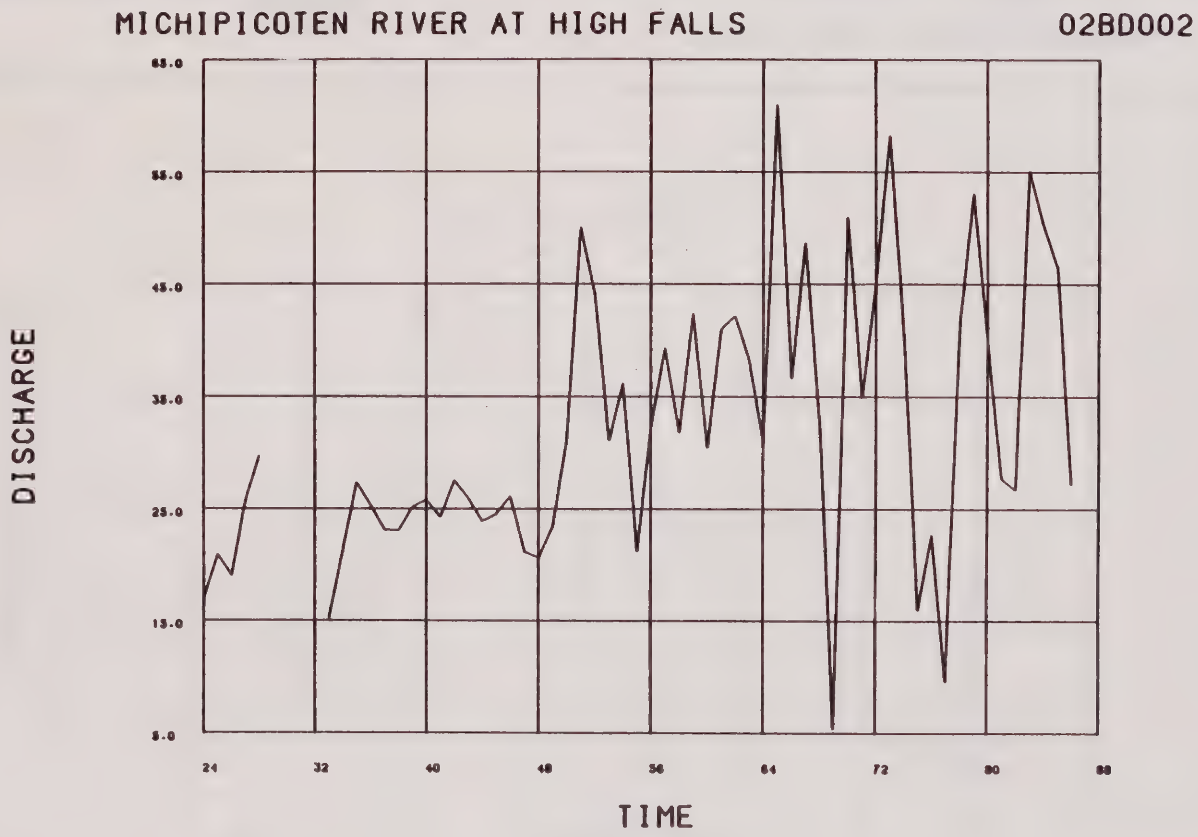
RANK VERSUS TIME
1958 - 1986

FIGURE 2



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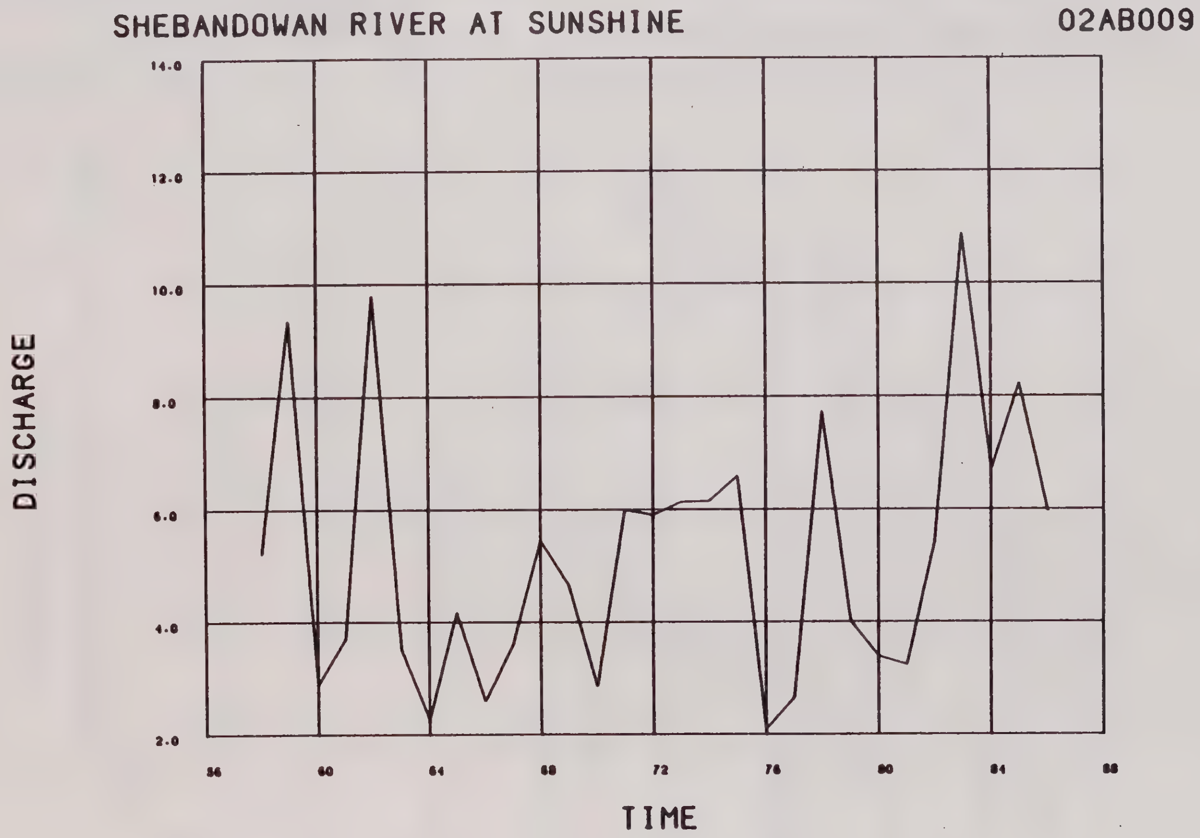
DISCHARGE VERSUS TIME
1924 - 1986

FIGURE 3



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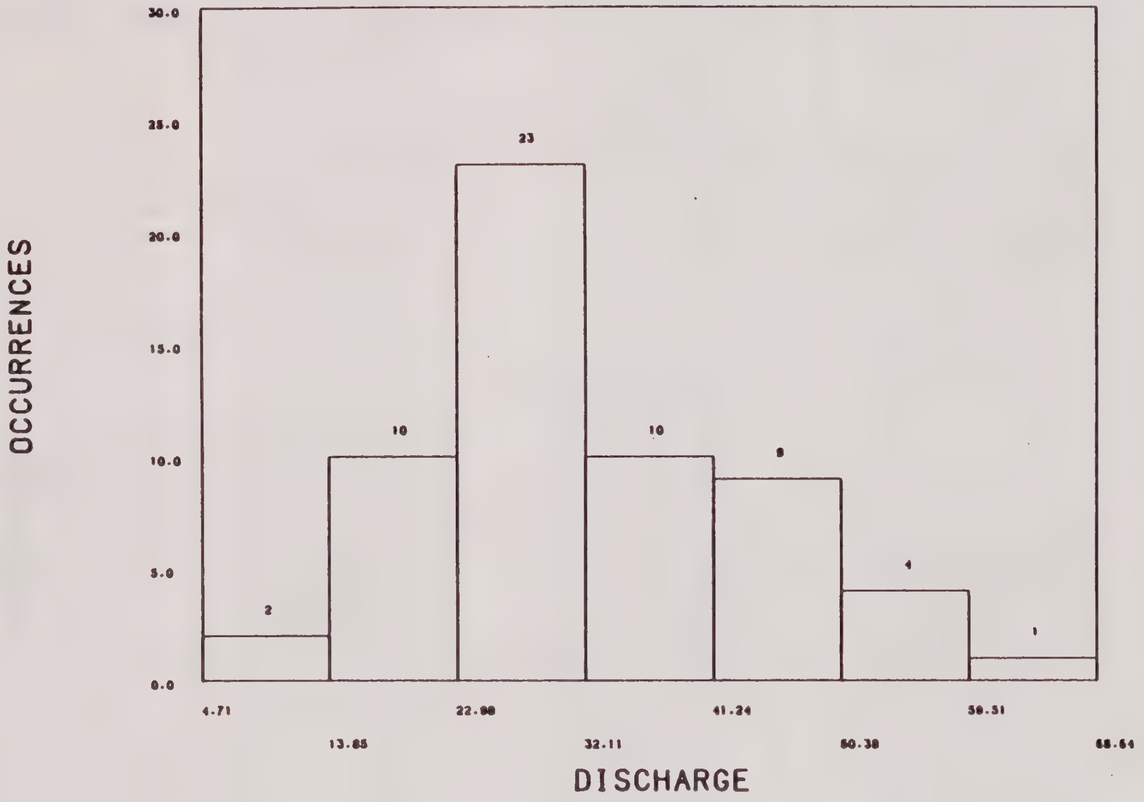
DISCHARGE VERSUS TIME
1958 - 1986

FIGURE 4

MICHIPICOTEN RIVER AT HIGH FALLS 02BD002



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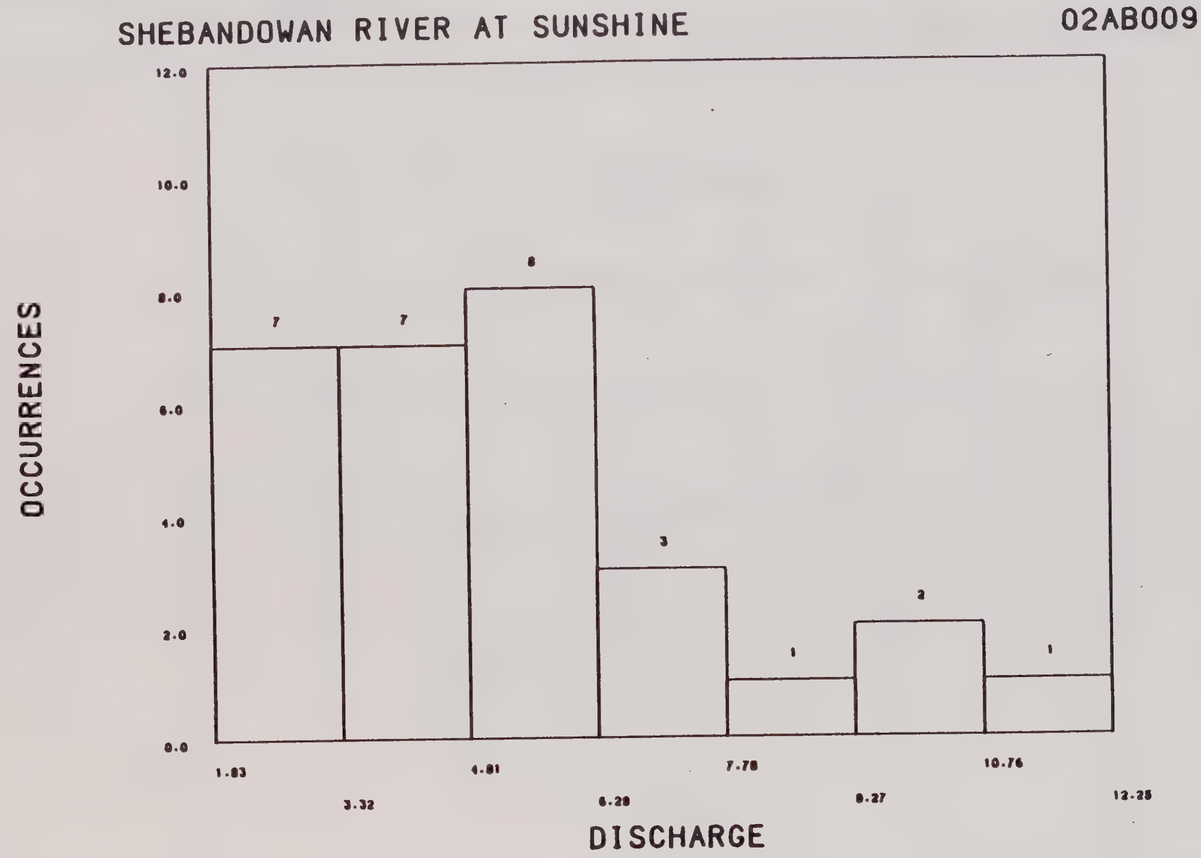
HISTOGRAM FOR DISCHARGE
1924 - 1986 59 OBSERVATIONS

FIGURE 5



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HISTOGRAM FOR DISCHARGE
1958 - 1986 29 OBSERVATIONS

FIGURE 5

TABLE 2

Summary of Data Screening All Stations

Northeastern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	53	7	0	47	13	0	50	10	0	43	17	0	46	19	0	46	19	0
3	51	9	0	44	13	0	48	12	0	43	17	0	47	18	0	46	19	0
7	50	10	0	44	16	0	50	10	0	41	19	0	47	18	0	48	17	0
15	51	9	0	46	16	0	53	7	0	42	18	0	46	19	0	48	17	0
30	54	6	0	46	14	0	50	10	0	44	16	0	49	16	0	48	17	0
* TOTAL	259	41		255	75		251	49		213	87		235	90		236	89	

Northwestern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	47	20	0	42	25	0	59	8	0	49	18	0	31	36	0	46	21	0
3	48	19	0	44	23	0	60	7	0	53	14	0	29	38	0	47	20	0
7	49	18	0	45	22	0	60	7	0	53	14	0	30	37	0	50	17	0
15	51	16	0	43	24	0	62	5	0	54	13	0	31	36	0	51	16	0
30	50	15	0	42	25	0	62	5	0	50	17	0	30	37	0	48	19	0
* TOTAL	247	88		216	119		303	32		259	76		151	184		242	93	

Southwest and West Central Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	72	26	0	66	32	0	57	40	0	44	54	0	17	84	0	67	34	0
3	71	27	0	68	30	0	54	44	0	43	55	0	18	83	0	68	33	0
7	72	26	0	66	32	0	58	40	0	42	56	0	19	82	0	71	30	0
15	74	24	0	67	31	0	57	41	0	44	54	0	17	84	0	73	28	0
30	71	27	0	65	33	0	54	44	0	41	57	0	17	84	0	70	31	0
* TOTAL	360	130		332	158		280	210		214	276		88	417		349	156	

Central Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	64	11	0	56	19	0	53	22	0	37	38	0	1	75	52	62	14	0
3	65	10	0	56	19	0	52	23	0	41	34	0	1	75	52	60	16	0
7	64	11	0	56	19	0	54	21	0	37	38	0	1	75	52	62	14	0
15	66	9	0	58	17	0	49	26	0	39	36	0	0	76	100	60	16	0
30	67	8	0	56	19	0	49	26	0	38	37	0	1	75	52	66	10	0
* TOTAL	326	49		282	93		257	118		192	183		4	376		310	70	

Southeastern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	39	7	0	37	9	0	41	5	0	36	10	0	22	27	0	36	13	0
3	39	7	0	36	10	0	43	3	0	38	8	0	22	27	0	37	12	0
7	40	6	0	39	7	0	43	3	0	41	5	0	23	26	0	37	12	0
15	41	5	0	37	9	0	43	3	0	42	4	0	23	26	0	40	9	0
30	43	3	0	39	7	0	44	2	0	39	7	0	24	25	0	40	9	0
* TOTAL	202	28		188	42		214	16		196	34		114	131		190	55	

* Total of the 5 durations for stations in this region

Dur : The duration the data set represents ie average 30 day low flow
Sig : The number of stations which show significant dependence, trend, non randomness
Not : The number of stations which show independence, free from trend, and randomness
Per : The percent binomial probability that this number of stations would fail the non parametric tests

Tables 3 and 4 show the results of data from $\geq$ 20 years of record with Table 3 showing less non-regulated stations than the regulated stations on Table 4. The regulated stations show a greater percentage of values which can be said to "pass" the non-parametric test compared to those which "failed". Although the Central Region data is showing computed randomness at the 1% level of significance, the binomial probability is still "0" for all other tests.

Tables 5 and 6 summarize the analysis results for stations with less than 20 years of record. The findings suggest that neither the length of record or the effect of regulation can account for the overall conclusion that the statistical tests indicate some degree of dependence, trend and non-randomness of the low flow data sets.

It is possible that application and interpretation of the non-parametric tests at the 10% level of significance could result in fewer statons "failing" the non-parametric tests.

TABLE 3

Summary of Data Screening
Non Regulated Stations With A Period of Record Greater Or Equal to 20 Years

Northeastern Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	12	0	0	11	1	0	11	1	0	10	2	0	8	4	0	11	1	0
3	12	0	0	10	2	0	11	1	0	10	2	0	8	4	0	11	1	0
7	12	0	0	11	1	0	12	0	0	10	2	0	8	4	0	11	1	0
15	12	0	0	10	2	0	12	0	0	10	2	0	8	4	0	11	1	0
30	12	0	0	10	2	0	11	1	0	10	2	0	8	4	0	11	1	0
* TOTAL	60	0		52	8		57	3		50	10		40	20		55	5	

Northwestern Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	10	7	0	10	7	0	15	2	0	12	5	0	11	6	0	13	4	0
3	10	7	0	10	7	0	15	2	0	13	4	0	11	6	0	14	3	0
7	10	7	0	10	7	0	15	2	0	13	4	0	11	6	0	14	3	0
15	12	5	0	10	7	0	15	2	0	14	3	0	11	6	0	14	3	0
30	12	5	0	10	7	0	15	2	0	12	5	0	11	6	0	12	5	0
* TOTAL	54	31		50	35		75	10		64	21		55	30		67	18	

Southwest and West Central Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	20	6	0	19	7	0	18	8	0	13	13	0	6	20	0	20	6	0
3	20	6	0	20	6	0	17	9	0	14	12	0	7	19	0	21	5	0
7	20	6	0	19	7	0	18	8	0	15	11	0	8	18	0	23	3	0
15	21	5	0	19	7	0	17	9	0	13	13	0	6	20	0	22	4	0
30	21	5	0	17	9	0	14	12	0	10	16	0	6	20	0	20	6	0
* TOTAL	102	28		94	36		84	46		65	65		33	97		106	24	

Central Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	21	3	0	17	7	0	15	9	0	11	13	0	0	24	100	20	4	0
3	21	3	0	17	7	0	16	8	0	13	11	0	0	24	100	21	3	0
7	21	3	0	18	6	0	16	8	0	11	13	0	0	24	100	19	5	0
15	21	3	0	19	5	0	14	10	0	10	14	0	0	24	100	19	5	0
30	22	2	0	18	6	0	14	10	0	10	14	0	0	24	100	21	3	0
* TOTAL	106	14		89	31		75	45		55	65		0	120		100	20	

Southeastern Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	6	1	0	6	1	0	6	1	0	5	2	0	2	5	0	5	2	0
3	6	1	0	5	2	0	6	1	0	5	2	0	2	5	0	5	2	0
7	6	1	0	5	2	0	6	1	0	5	2	0	2	5	0	5	2	0
15	6	1	0	5	2	0	6	1	0	6	1	0	2	5	0	6	1	0
30	7	0	0	6	1	0	6	1	0	4	3	0	2	5	0	6	1	0
* TOTAL	31	4		27	8		30	5		25	10		10	25		27		

* Total of the 5 durations for stations in this region

Dur : The duration the data set represents ie average 30 day low flow
Sig : The number of stations which show significant dependence, trend, non randomness
Not : The number of stations which show independence, free from trend, and randomness
Per : The percent binomial probability that this number of stations would fail the non parametric tests

TABLE 4

Summary of Data Screening
Regulated Stations With A Period Of Record Greater Or Equal To 20 Years

Northeastern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	21	7	0	16	12	0	20	8	0	15	13	0	21	9	0	15	15	0
3	19	9	0	14	14	0	18	10	0	15	13	0	22	8	0	15	15	0
7	18	10	0	14	14	0	19	9	0	13	15	0	22	8	0	18	12	0
15	19	9	0	15	13	0	22	6	0	14	14	0	21	9	0	18	12	0
30	22	6	0	16	12	0	20	8	0	15	13	0	24	6	0	17	13	0
* TOTAL	99	41		75	65		99	41		72	68		110	40		83	67	

Northwestern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	12	12	0	9	15	0	19	5	0	14	10	0	10	14	0	11	13	0
3	14	10	0	11	13	0	20	4	0	16	8	0	8	16	0	12	12	0
7	15	9	0	12	12	0	20	4	0	18	6	0	9	15	0	14	10	0
15	14	10	0	11	13	0	22	2	0	18	6	0	10	14	0	15	9	0
30	15	9	0	10	14	0	22	2	0	16	8	0	9	15	0	15	9	0
* TOTAL	70	50		53	67		103	17		82	38		46	74		67	53	

Southwest and West Central Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	30	18	0	25	23	0	18	30	0	13	35	0	5	44	0	28	21	0
3	29	19	0	26	22	0	16	32	0	12	35	0	5	44	0	29	20	0
7	29	19	0	24	24	0	19	29	0	12	36	0	5	44	0	28	21	0
15	29	19	0	25	23	0	18	30	0	16	32	0	5	44	0	29	20	0
30	26	22	0	24	24	0	18	30	0	12	36	0	5	44	0	27	22	0
* TOTAL	143	97		124	116		89	151		65	175		25	220		141	104	

Central Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	25	8	0	22	11	0	21	12	0	15	18	0	1	32	27	25	8	0
3	26	7	0	22	11	0	20	13	0	16	17	0	1	32	27	21	12	0
7	25	8	0	22	11	0	22	11	0	15	18	0	1	32	27	25	8	0
15	27	6	0	23	10	0	19	14	0	16	17	0	0	33	100	23	10	0
30	28	5	0	22	11	0	19	14	0	14	19	0	1	32	27	27	6	0
* TOTAL	131	34		111	54		101	64		76	89		4	161		121	44	

Southeastern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	13	6	0	12	7	0	15	4	0	13	6	0	5	14	0	12	7	0
3	13	6	0	11	8	0	17	2	0	15	4	0	5	14	0	13	6	0
7	14	5	0	14	5	0	17	2	0	17	2	0	6	13	0	13	6	0
15	15	4	0	12	7	0	17	2	0	17	2	0	6	13	0	15	4	0
30	16	3	0	13	6	0	18	1	0	16	3	0	7	12	0	14	5	0
* TOTAL	71	24		62	33		84	11		78	17		29	66		67	28	

* Total of the 5 durations for stations in this region

Dur : The duration the data set represents ie average 30 day low flow
Sig : The number of stations which show significant dependence, trend, non randomness
Not : The number of stations which show independence, free from trend, and randomness
Per : The percent binomial probability that this number of stations would fail the non parametric tests

TABLE 5

Summary of Data Screening
Non Regulated Stations With A Period Of Record Less Than 20 Years

Northwestern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	19	1	0	17	3	0	19	1	0	17	3	0	8	12	0	16	4	0
3	18	2	0	17	3	0	19	1	0	18	2	0	8	12	0	15	5	0
7	18	2	0	17	3	0	19	1	0	16	4	0	8	12	0	16	4	0
15	19	1	0	16	4	0	19	1	0	16	4	0	8	12	0	16	4	0
30	19	1	0	16	4	0	19	1	0	16	4	0	8	12	0	15	5	0
* TOTAL	93	7		83	17		95	5		83	17		40	60		78	22	

Northeastern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	14	0	0	14	0	0	13	1	0	12	2	0	11	3	0	14	0	0
3	14	0	0	14	0	0	13	1	0	12	2	0	11	3	0	14	0	0
7	14	0	0	13	1	0	13	1	0	12	2	0	11	3	0	13	1	0
15	14	0	0	13	1	0	13	1	0	12	2	0	11	3	0	13	1	0
30	14	0	0	14	0	0	13	1	0	13	1	0	11	3	0	14	0	0
* TOTAL	70	0		68	2		65	5		61	9		55	15		68	2	

Southwest and West Central Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	16	2	0	16	2	0	16	2	0	14	4	0	4	16	0	13	7	0
3	16	2	0	16	2	0	16	2	0	14	4	0	4	16	0	12	8	0
7	17	1	0	17	1	0	16	2	0	12	6	0	4	16	0	14	6	0
15	18	0	0	17	1	0	17	1	0	11	7	0	4	16	0	16	4	0
30	18	0	0	18	0	0	17	1	0	15	3	0	4	16	0	17	3	0
* TOTAL	85	5		84	6		82	8		66	24		20	80		72	28	

Central Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	10	0	0	9	1	0	9	1	0	5	5	0	0	10	100	9	1	0
3	10	0	0	9	1	0	9	1	0	5	5	0	0	10	100	10	0	0
7	10	0	0	9	1	0	9	1	0	5	5	0	0	10	100	10	0	0
15	10	0	0	9	1	0	9	1	0	6	4	0	0	10	100	10	0	0
30	10	0	0	9	1	0	9	1	0	7	3	0	0	10	100	10	0	0
* TOTAL	50	0		45	5		45	5		28	22		0	50		49	1	

Southeastern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	8	0	0	7	1	0	8	0	0	7	1	0	7	3	0	7	3	0
3	8	0	0	8	0	0	8	0	0	7	1	0	7	3	0	7	3	0
7	8	0	0	8	0	0	8	0	0	8	0	0	7	3	0	7	3	0
15	8	0	0	8	0	0	8	0	0	8	0	0	7	3	0	7	3	0
30	8	0	0	8	0	0	8	0	0	8	0	0	7	3	0	8	2	0
* TOTAL	40	0		39	1		40	0		38	2		35	15		36	14	

* Total of the 5 durations for stations in this region

Dur : The duration the data set represents ie average 30 day low flow
Sig : The number of stations which show significant dependence, trend, non randomness
Not : The number of stations which show independence, free from trend, and randomness
Per : The percent binomial probability that this number of stations would fail the non parametric tests

TABLE 6

Summary of Data Screening
Regulated Stations With A Period Of Record Less Than 20 Years

Northwestern Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	0
3	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	0
7	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	0
15	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	0
30	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	0
* TOTAL	30	0		30	0		30	0		30	0		10	20		30	0	

Northeastern Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
3	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
7	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
15	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
30	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
* TOTAL	30	0		30	0		30	0		30	0		30	15		30	15	

Southwest and West Central Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	6	0	0	6	0	0	5	1	0	4	2	0	2	4	0	6	0	0
3	6	0	0	6	0	0	5	1	0	3	3	0	2	4	0	6	0	0
7	6	0	0	6	0	0	5	1	0	3	3	0	2	4	0	6	0	0
15	6	0	0	6	0	0	5	1	0	4	2	0	2	4	0	6	0	0
30	6	0	0	6	0	0	5	1	0	4	2	0	2	4	0	6	0	0
* TOTAL	30	0		30	0		25	5		18	12		10	20		30	0	

Central Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	8	0	0	8	0	0	8	0	0	6	2	0	0	9	0	8	1	0
3	8	0	0	8	0	0	7	1	0	7	1	0	0	9	0	8	1	0
7	8	0	0	7	1	0	7	1	0	6	2	0	0	9	0	8	1	0
15	8	0	0	7	1	0	7	1	0	7	1	0	0	9	0	8	1	0
30	7	1	0	7	1	0	7	1	0	7	1	0	0	9	0	8	1	0
*TOTAL	39	1		37	3		36	4		33	7		0	45		40	5	

Southeastern Region

Day Duration	Independence						Trend						Randomness					
	1%			5%			1%			5%			1%			5%		
	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
3	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
7	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
15	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
30	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
* TOTAL	60	0		60	0		60	0		55	5		40	25		60	5	

* Total of the 5 durations for stations in this region

Dur : The duration the data set represents ie average 30 day low flow
Sig : The number of stations which show significant dependence, trend, non randomness
Not : The number of stations which show independence, free from trend, and randomness
Per : The percent binomial probability that this number of stations would fail the non parametric tests